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JOURNAL

OF THE

AMERICAN WELDING SOCIETY

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33 West Thirty-ninth Street, New York

American Welding Society

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AMERICAN WELDING SOCIETY

ESTABLISHED 1919

JOURNAL

Volume 3 June, 1924 Number 6

OUR FIRST MEMBERSHIP DIRECTORY

Plans for publication of the first Membership Directory of the Society as the August issue of the Journal are well under way. Every member will shortly receive a blank card on which he is expected to furnish his address and connections in order that the directory may contain full and up to date information. Your co-operation is requested in returning these cards promptly as the compilation of the directory should begin without delay.

MEMBERSHIP DRIVE

The Membership Committee requests your assistance in putting over the top a membership drive, the slogan of which is, "A Thousand Members in our First Membership Directory."

Each local section has been assigned a certain quota to fill. This quota can only be filled with your assistance. Every member of the Society must know at least one or two of his friends who should be affiliated with us. The amount of work which the Society can do is in direct proportion to its number of members. The Membership Committee earnestly requests that you do your bit now, by getting at least one new member at once, as all the names of these new members must be in the Society's office not later than the 15th of July if they are to be included in the directory.

A circular letter is being sent to a number of prospective members direct from national headquarters. This letter is reproduced below:

TO THOSE INTERESTED IN METALS AND THEIR USES:

Gentlemen:

The first membership directory of the American Welding Society will be issued Aug. 1, 1924. We want to include in it all the names of people who are identified in any way with the welding industry. This directory will be the blue book of the welding fraternity. It will be used as a mailing list for all sorts of pamphlets, technical bulletins and items of interest to those in the welding field. In order to have your name included you must become a member at once—in any event not later than July 10th.

There is inclosed for your careful consideration a little leaflet describing the Society and its various activities and an application blank showing the various classes of members and the dues for each. Membership in the American Welding Society will unquestionably assist you in your daily problems and prove its value to you as to our present members.

Five years have passed since the organization of the American Welding Society. Since that time the applications of welding have increased more than four fold. The mystery connected with the various processes has largely disappeared. Although the surface of knowledge has only been scratched, we are in a position to specify methods, technique and materials with a degree of certainty that comes only from test results and service experience. The American Welding Society has at its command the combined knowledge, wisdom and experience of the leading welding experts, engineers and practical men of the country. Through its coordinating influence and its concentration of application it has helped to overcome difficulties which a few years ago were thought insurmountable.

Everyone interested in the use of welding, be he a manufacturer of welding apparatus, a user of various welding processes, a welding engineer or a welder, has directly or indirectly benefited through the work of the American Welding Society. It would only be fair to ask you to return a

small percentage of these profits as membership dues in order to permit the Society to continue with its work and increase its activities.

As a matter of fact, the membership dues are a very small part of the funds received by the Society and used by it in extending the knowledge of welding. As an example, last year the Society received from all the Class D members approximately $3,000, whereas its total expenditure of funds received from all sources including advertising was over $21,000. As the Class D members receive the Journal, reports of the Bureau and benefits of section meetings and other activities of the Society, they practically receive the benefits of the entire expenditure of $21,000, which would mean a return on the investment by Class D members of 700 per cent. If one were to consider the actual expenditure on research work, the benefits of which accrue to the members of the Society this percentage could easily be multiplied by 100.

The medium of communication of the Society with its members is the Journal published monthly, which is distributed free to all members. In this Journal are published all the news of the Society and its local sections, technical papers on welding and reports of the research department of the Society (American Bureau of Welding), employment service bulletin, current welding literature and a technical question and answer column.

The possibilities of welding are enormous and the returns which members of the Society may expect is in direct proportion to these possibilities. As a member you are kept abreast of all the latest developments, of all new information and of the results of experience of others.

Yours very truly,
C. A. McCUNE,
Chairman, Membersip Committee.

ANNUAL REPORT OF PRESIDENT

There is given elsewhere in these columns the annual report of our Past President, Mr. T. F. Barton. It includes a review of what has transpired during the past year and at the same time points out the path to still greater accomplishments. In many instances it also indicates the obligations of membership in the Society and therefore every member is respectfully urged to give this report his most careful consideration.

RESOLUTION ADOPTED BY THE AMERICAN WELDING SOCIETY CONCERNING THE RETIREMENT OF MR. HERMANN LEMP FROM ACTIVE PARTICIPATION IN ITS WORK

Preamble

Just as the seed determines the type of the flower and fruit, while the quantity and quality is in part determined by the care and nourishment of the growing plant, so the type of the fruit born by an organization like this Society of ours is largely determined by the ideals planted by the founders. In the case of some of the founders of the American Welding Society the work was done with business or industrial ends in view although not necessarily without high ideals; in the case of some others it was largely a labor of love, urged on by loyalty to an ideal, although not without full appreciation of the industrial ends.

One of the most vigorous and active members of this latter group is our dear friend Hermann Lemp, whose fearless support of his ideals, whose cheerful, loyal and indefatigable service to the Society has not only been an inspiration to his co-workers, but has endeared him to us all in a manner that deserves some permanent record.

Resolution:

Whereas: Mr. Hermann Lemp, Member of the Board of Directors of the American Welding Society, Chairman, Committee on By-Laws, American Welding Society and Chairman, Committee on Resistance Welding, American Bureau of Welding has found it necessary to withdraw from active participation in the work of these bodies, and, the support and cooperation he has so freely and fully given from the inception of the Society have been principal factors in its growth; and the technical resource and practical experience he has brought to bear on the conduct of investigations and solution of problems arising out of the development of the Society's work is a distinct loss which cannot easily be replaced.

Be it resolved: That the American Welding Society at its annual convention accepts the resignation of our esteemed friend and counsellor only with the sincerest regret and wishes to express the hope that

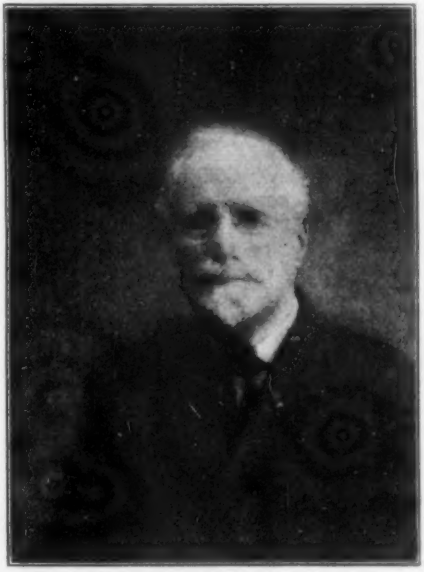
the Society may continue to benefit by his membership if only in advisory capacity. Further that we wish Mr. Lemp many years of continued service, success and happiness in his chosen field. That this resolution be spread upon the minutes of this meeting and the Secretary transmit a certified copy to Mr. Lemp.

HERMANN LEMP

Biographical Sketch

Hermann Lemp, born in Bern, Switzerland, August 8, 1862, was educated there and at Zurich, Burgdorf and Neuchatel, graduating in 1878, and then becoming student electrician in Mathias Hipp's Works, Neuchatel, makers of electric clocks and precision instruments. Edison's memorable exhibit at the first electrical exhibition in Paris in 1881 led him to come to America and successfully seek employment in Edison's Laboratory where he spent a year.

He was afterward associated with Merle J. Wightman in development of the series incandescent lamp system of the Schuyler Electric Co., Hartford, Conn.; became assistant to Professor Elihu Thomson in his laboratory at Lynn, Mass.; Chief Engineer of the Thomson Electric Welding Co., 1889, and since 1896 has been connected with the General Electric Co.; was sent abroad in 1911 to study Diesel engines, and on his return was transferred to the Erie works to assist in the development of high-compression, oil-engined electric lighting sets. Alone or with others, he has taken out more than 300 patents,



many of them basic. He is a Fellow of the American Institute of Electrical Engineers, a Charter Member of the American Welding Society and distinguished in the profession.

President's Report of Year's Activities

T. F. Barton

In looking back over the past year, I am impressed at once with the accomplishments of the Society and the opportunities for still greater service.

Purpose:

The opening paragraphs of our Constitution state that we are organized (a) to advance the science and art of welding. (b) To afford its members an opportunity for the interchange of ideas with respect to the science and art of welding and for the publication of information thereon. The degree to which we have realized these objectives is indicated by the recognition accorded to our specifications, standards and reports and demands made upon us by the industrial world for assistance in solving problems and furnishing information.

Technical Work

The advancement of welding may be divided under many headings but the following are to my mind of the utmost importance. 1. Securing, assembling, interpreting and spreading broadcast all available welding data of value. 2. Definite methods for the training of operators who are to perform the works together with other definite standards. 3. Recommendations for increasing the applications of welding. The latest available information and recommended practices, standards and specifications in welding is given to every

member of this Society through our monthly Journal. The information contained in this publication is of inestimable value. The many letters of commendation of various technical and industrial organizations the world over are the best testimonial of this fact. Being a railroad man charged with the responsibility of properly maintaining equpment, I assure you that the value of standards is well known and appreciated by me.

The director of the American Bureau of Welding in his annual report pointed out some of the remarkable accomplishments of our research department during the past year. This means that each of us is getting the benefits of results of many thousands of dollars of investigational work contributed by interested companies and a still larger amount in the way of services of the foremost welding experts in the country.

The training of operators has for years been considered by many to be the real stepping stone to successful welding and it has often been referred as being responsible for 80 per cent of the efficiency of a good weld. Through the untiring efforts of our committee on the Training of Operators a course has been arranged and is now available for both gas and electric welding. The men who have worked on this course have been a big factor in tearing aside what was formerly termed the veil of secrecy and through the Society have opened the gateway to better welding.

It may be thought by some that we have been neglectful to some extent in our recommendations for increasing welding applications, but I believe that the columns of our Journal have brought forth many new thoughts and have been responsible for welding in places where it had not existed before. We have letters from the industry substantiating this.

Value of Papers

How many of us realize in reading over an important paper given in our Journal, the actual cash contribution that it represents. Sometimes the conclusions expressed in such papers are the results of years of effort and study involving an expenditure of huge sums. Let us imagine that there were no sources for the dissemination of welding information or machinery for getting the benefits of the other fellow's experience and work and passing along your own. This would probably result in excessive duplication and waste of time, retardation of the industry and meeting every day problems which with your own limited facilities would be insurmountable.

Affiliation with National Research Council

Our members are aware of the fact that the American Bureau of Welding acts as the welding research department of both the Society and National Research Council. The question sometimes asked is what is the exact status of this affiliation and what are its advantages.

National Research Council was organized during the war to coordinate the scientific talent of the country in solving war problems. It still enjoys a semi-governmental standing in that all governmental departments are ordered to cooperate with it. Moreover it is a recognized national organization for the promotion of research and has a very high standing as an unbiased authority.

Through our affiliation with the Council we are able to take advantage of its organizational experience in setting up the necessary machinery to solve the more complicated problems of welding. We are able to secure the cooperation of many large companies, university laboratories and laboratories of the governmental departments such as for example the Bureau of Standards. Pronouncements of our research committees are regarded as unbiased and authoritative. Even the financing of research projects where it is found necessary is rendered very much easier through the wide contacts of the Council.

Aside from this a large part of the overhead of the American Bureau of Welding is borne directly from the funds of the Council.

Exchange of Information

I would like to call to your attention one of the benefits of Society and Committee meetings that is sometimes overlooked. The direct benefits of papers presented by speakers and reports of Committees are usually quite apparent but on the other hand benefits of "getting together" with people of allied interests are not always so tangible. However, the op-

portunity to get together and talking things over before, during and after meetings sometimes results in the obtaining of new ideas and suggestions how to overcome difficulties, of passing to the next fellow the results of your experience. Sometimes these informal talks are worth as much if not more than the regular scheduled papers.

Organization and Membership

The remarkable success of our short existence must not blind us to opportunities still existing.

We are out of the woods now as far as our organization difficulties are concerned. Our finances are in good shape and our membership is a healthy one, although not as large in numbers as it should be.

It is almost impossible to calculate the number of men who are engaged directly in welding or responsible for work either in which welding is applied or to which welding could be applied and I only wish that it would be possible to get 50 per cent of these men who are not members to attend the monthly meetings of our various sections, where they would soon realize that their problems were in common with ours.

Obligations on the Part of Members

Membership in the Society carries with it far greater obligations than payment of dues. If that is all you are doing you are not contributing your just share. You are receiving the benefits of information contained in papers presented before sections and published in the Journal of the Society. It would only be a just return on your part for you to contribute from time to time the results of your experience and thus help the other fellow out.

Moreover, solicitation of new members cannot be successfully done by a chosen few called the "Membership Committee." Every member of the Society must constitute himself a Membership Committee. If for instance, every member of the Society were to each year secure just one additional member our membership would be doubled each year. At the end of four years we would have over 10,000 members. The accomplishments of the efforts of a united 10,000 members would be miraculous. Opportunities for advancement would at once be created for everyone connected with the welding industry even in the remotest way.

A budget has been prepared by the National body and a substantial amount has been set aside for an advertising campaign and the support of missionary work in the promotion of the Society and the securing of members. In this promotion and missionary work, the entire membership will be called on to do its part. Our members know what advantages they have received from the Society during the past and previous years and are therefore well qualified to talk convincingly on the benefits to be derived from membership in our Society.

Section Activities

We have organized at the present time eleven sections, some of which have been operating since the Society was organized, others for the past two years and two during the past few months.

Some of these sections hold very successful and well attended meetings. On the other hand the performance of others is a striking indication of the necessity for following the advice of our Meetings and Papers Committee that each section lay out its program for the year very early in the fall. Last minute arrangements for meetings are bound to be unsuccessful. Busy experts and authorities on welding subjects cannot be secured at a moment's notice. Their plans are laid well in advance. Moreover, notices sent out at the last minute (an uncalled for delay due to last minute preparation of meetings) arrive after many members have made previous engagements and other plans. As a result, meetings are not well attended and one failure is followed by another as the effect of unsuccessful meetings on members is accumulative.

There is a certain degree of responsibility on the part of members to make meetings successful. Even the most Herculean efforts on the part of section officers in securing the best speakers available cannot make meetings successful if the members do not attend these meetings. The efforts of your section officers and courtesy to the speakers deserves your careful consideration.

Fortunately from a financial standpoint the sections are all in good shape but the membership of each section is by no means representative of the interest in welding that is being practiced. I would suggest that each section set aside a definite

sum of money to be spent on the local promotion of the section.

Fall Meeting of the Society

Our 1923 fall meeting at Pittsburgh in October was complete evidence of what the industry thinks of our Society. A review of the registration at that meeting showed that over 15 per cent of all the members present were from locations other than Pittsburgh. The attendance at the Industrial Application Session was a revelation to many non-members. More than half those present accepted the invitations of the Westinghouse Electric & Mfg. Co. and the Carnegie Steel Co. to inspect their plants and they were well repaid. At the joint meeting of the Society and the Pittsburgh Section, the Society was honored with enlightening addresses by men of national reputation such as Dr. A. D. Risteen, Director of Technical Research, Travelers' Insurance Co. and Mr. George Ogden, Traffic Manager of the Pennsylvania System and President of the Pittsburgh Railway Club.

Membership Directory

There are many things which we have postponed doing from year to year in order to preserve our finances. One of these was the publication of a membership directory. Our files are full of correspondence asking for a directory of this kind and I am happy to report that we expect to publish the directory during the month of August this year and from now on it is our hope to use the August number of our Journal as a year book and directory.

Expenditures of Society

It is difficult to state to what extent our receipts and expenditures represent our responsibility for increasing welding but I believe the figures will be of interest to you.

For the year ending March 31, 1922, our receipts were $8,534.90; expenditures, $11,037.98.

For the year ending March 31, 1923, our receipts were $16,793.92; expenditures, $16,843.04.

For the year ending March 31, 1924, our receipts were $23,472.67; expenditures, $21,202.99.

Take the year ending March 31, 1924, as an example; we have received in dues from the Class D members, the total sum of $3,000. Compare this to the expenditure of $21,000 and it is readily seen that this represents to the Class D members an interest on the investment of 700 per cent. This money was all spent in accomplishments from which the members received positive direct benefit, and if these figures are taken as a criterion of the same advance in welding, it will be readily seen that welding has increased more than 100 per cent in the last two years. Unquestionably the Society has played a leading part in this advancement. We have, therefore, passed beyond the stage of hopes and in a measure have reached the point of realization of our hopes and our members should feel proud to know that they have played so prominent a part in the fostering and promotion of a process that has proven itself economical and has made possible the production and maintenance of parts which were thought impossible heretofore.

Acknowledgments

In closing I would indeed be ungrateful if I did not tell you how much I personally appreciate the support given me during my administration. I was fortunate in having the good advice and assistance of the men who served before me and without them my administration would not have been successful. These men who include industrialists, apparatus manufacturers and users of welding equipment, have zealously worked to give to the industry their best and how well they have succeeded is indicated by the healthy condition of the Society and the honorable position it holds in the technical world.

The spirit manifested by your past officers is a praiseworthy one. It has been mighty hard indeed I assure you to keep up with the progress made by them. They have set a very strong pace. I realize now more than ever the way the Society has developed to its present stage and this is due not only to the fact that your Past Presidents worked very hard while they were in office but that they have worked practically as hard for the success of the man who came after them, and, gentlemen, it is my fond hope to join with them in rendering to your incoming President the same cooperation which they have rendered me. To have served you as President has indeed been a very great honor and I will look back to this time and to the many new friends I have made by being associated with you with a great deal of pleasure.

Section Activities

Philadelphia

The May meeting of the Philadelphia Section was held on May 19 in the Auditorium of the Engineers Club. Mr. J. W. Belanger of the General Electric Company presented a very interesting address illustrated with lantern slides on "Automatic Arc Welding."

The chairman also outlined a program for meetings and papers for the coming year:

Northern New York

The May meeting of this section was held on the 23rd in the Engineering Building of Union College. Mr. Walcott Remington, chief engineer of the Thomson Electric Welding Company presented an illustrated lecture on "Applications of Resistance Welding to Modern Industry."

Chicago

The Chicago Section of the American Welding Society met in the rooms of the Western Society of Engineers, in the Monadnock Building, Chicago, on May 2. Mr. Fred J. Maeurer presented the Air Reduction Sales Company's motion picture film, entitled "Oxygen, the Wonder Worker." This was the first showing of this film since it has been revised and lengthened. Many new features have been added to it. Mr. Maeurer lectured upon the subject in an extremely interesting manner.

The film illustrates the various stages in the manufacture of oxygen, giving details of the process as it progresses within the compressors, separators, columns, etc. It also illustrates many instances of welding and cutting, and many of the details of manufacture in an acetylene plant.

After Mr. Maeurer's lecture and the showing of the film those present, about 140 in number, were served a buffet luncheon. This was the last meeting of the season.

A meeting of the Board of Directors of the Chicago Section will be held on June 5 to discuss the fall and winter program.

San Francisco

The May meeting of the San Francisco section was held on the 16th in the Engineers' Club. Mr. H. A. Patterson, foreman welder of the Atcheson, Topeka & Santa Fe R. R. presented a paper on "Job Welding Practice on the Santa Fe."

MEMBERSHIP DRIVE

The assistance of every member of the Society is needed in making our Membership Drive a success. If you know of a prospective member, advise this office or your Section Chairman of his name and address.

EMPLOYMENT SERVICE BULLETIN

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the BULLETIN.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the thirtieth of the month if publication in the following issue is desired. *ALL REPLIES should be Addressed to the Number Indicated in Each Case and Mailed to Society Headquarters.*

Positions Vacant

V-16. Manager wanted to take charge of Chicago office of manufacturer of electric welding equipment. Should have (1) intimate knowledge of electric welding, both arc and resistance, (2) experience in sale of electric welding machines, preferably, but not essentially, in the Chicago district. Please cover these points fully in your first letter.

V-17. Need a young salesman who understands the operation of welding and cutting apparatus, to assist us in selling our oxy-acetylene welding and cutting equipment in the eastern territory.

Services Available

A-23. Welder desires position. Have taken the General Electric Training Course and have had five months' experience with the General Electric Co. on welding wheels, oil switch vessels, gear cases and welding tanks with semi-automatic welding machine. Have also had four years' experience with Ferrocarril Central Dominicano R. R., welding oil tanks, building up shafts for locomotives, frogs, cast iron gears, locomotive frames, etc.

EMBLEM

All members of the Society are privileged to wear the Society emblem. Emblems may be obtained in two styles from the Secretary's office.

Price, gold-filled, 75c; 14-K. gold, $5.00.

ELECTRIC WELDING OF LARGE STORAGE TANKS*

HAROLD C. PRICE†

One year ago, that is in January, 1923, there had not been constructed a single oil-storage tank of 55,000-bbl. or more capacity with a completely electric welded roof and bottom. Today there are at least fifty 80,000-bbl. storage tanks completed, or nearing completion, on which both the roofs and the bottoms are electric welded. It is the purpose of this paper to describe, in a general

FIG. 1—ELECTRIC-WELDED SEAMS AND RIVETS OF BOTTOM IN 55,000-BBL. TANK AT EL DORADO, KAN., SHOWING ALSO PATCH PLATE WELDED TO BOTTOM

way, the construction of these welded roofs and bottoms, and to give their advantages over riveted construction. All of the following data and conclusions were obtained from observations made during the welding of tanks by the Welding Engineering Co. at Texas City, Tex., and Tonkawa and Burbank, Okla.

As far as can be determined, the first electric welding on large tankage was completed in May, 1922. At that time the Empire Companies of Bartlesville, Okla., discovered a badly leaking bottom in a 55,000-bbl. tank at El Dorado, Kan. They had considered concreting this bottom, but because of the much smaller cost, decided to try electric welding; so a contract was given the Welding Engineering Co. of Bartlesville, Okla. In this instance, no new sheets were added, the bottom being repaired by electric welding of all seams and rivets, Fig. 1. In some places where the original rivets were missing, the holes were filled by welding; patch plates were also added at certain badly worn spots. This tank has since been in service over a year and half, but no other leaks have been discovered. The cost of electric welding was about one-half that of a concrete bottom.

*Reprinted from Transactions of American Institute of Mining and Metallurgical Engineers.

†Manager, Welding Engineering Co. of Bartlesville, Okla.

Shortly after this, the Cosden Company began to electric-weld the roof seams on the storage tanks at its refinery at Tulsa. These, however, were riveted roofs, the rivets being laid at a pitch of 4 in. The welding, therefore, on these roofs simply took the place of the caulking edge, and was not applied for strength. According to the officers of the company, welding has furnished a gas-tight roof.

The Standard Oil Co. did some similar work at Neodesha, Kan., during this period. In the latter part of 1922 one of the large tank-construction companies erected the first all-welded roof at Humboldt, Kan., but the real construction of both roofs and bottoms did not begin until February, 1923. At that time the Marland Refining Co. let a contract to the Welding Engineering Co. to repair three 55,000-bbl. tanks at Texas City, Tex. All the seams and rivets in the bottoms of these tanks were to be welded, as were all the seams in the shell. The tanks to be repaired were hardly a year old, two of them had never been filled with oil, yet the rivets and seams were leaking badly. With the expense of these repairs in mind the Marland Refining Co. decided that it would save considerable money if the bottoms and roofs of all tanks were welded during the original construction; therefore, contracts were awarded for nearly fifty tanks at Texas City, Tex., Ponca City, Tonkawa and Burbank, Okla., with electric welded roofs and bottoms.

Erection

As there are no holes to be punched in the plates, the sheets for this work, with the exception of the sketch plates, are shipped direct from the mill to the job, without going through the shops. In most cases the sketch plates are cut in the shop; sometimes they are cut in the field by the use of an acetylene torch. The first method is the better and cheaper, for when the sketch plates are cut in the field there is considerable waste of material; also unless the film of oxide left by the acetylene is thoroughly removed from the plate there is likely to be considerable leakage through the weld. After the grade for the tank is made, the bottom sheets are laid directly upon it; no horses or scaffolding are necessary, as when the bottoms are riveted. All plates, both roof and bottom, are laid with a 1-in. lap. The bottom plates are first laid in position and tack-welded, after which the angle iron is placed in position, tack-welded, and then completely welded to the bottom, Fig. 2. After the angle iron has been completely welded to the bottom, the shell of the tank is raised and riveted, while the welding of the bottom sheets is being completed. The shell of the tank is riveted and the structural steel for the roof is erected in the usual manner, Fig. 3.

The roof plates are then raised, by the means of a cam or screw clamp, and laid, in the usual manner, from the edge toward the center. They are tacked to the top angle and to each other as

they are laid, Figs. 4 and 5. The first method was to tack the plates on the ends and in the center, in order to expedite the laying;

FIG. 2—WELDING ANGLE IRON TO BOTTOM

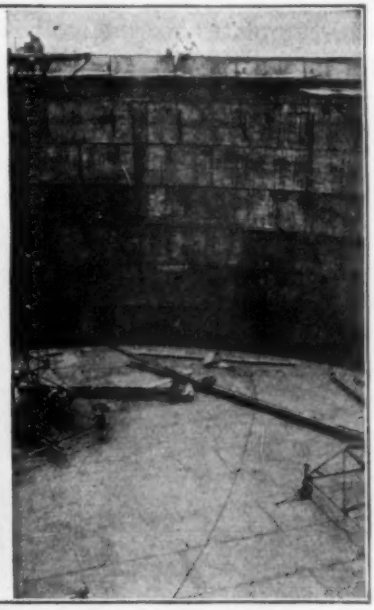


FIG. 3—FINISHING WELDING ON BOTTOM AS SHELL IS BEING COMPLETED

FIG. 4—TACKING FIRST COURSE OF ROOF

FIG. 5—TACK-WELDING FIRST PLATE TO ANGLE IRON ON 55,000-BBL. STORAGE TANK FOR MARLAND REFINING CO., AT TEXAS CITY, TEX.

a second welder would then permanently tack with a 12-in. spacing, Fig. 6. But by this method, because of buckling between the temporary tacks, it was often necessary to use weights or leverage to bring the plates in contact with each other. Later, two welders tacked simultaneously on each plate, working in one direction only; this eliminated the buckles and the necessity of further tacking.

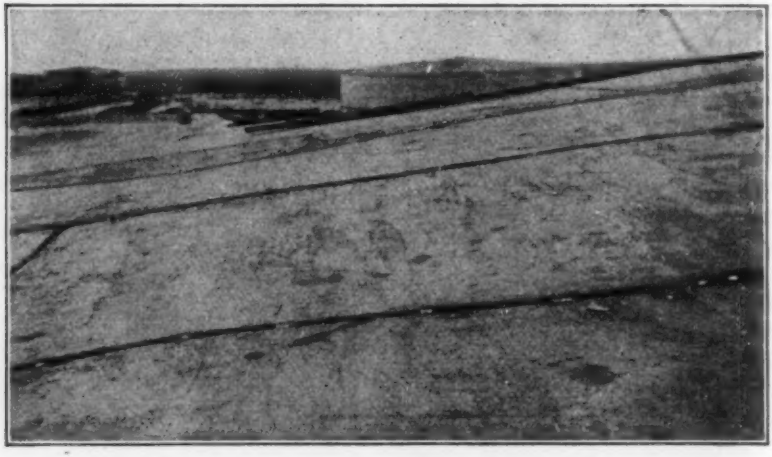


FIG. 6—ROOF PLATES TACK-WELDED READY FOR FINAL WELDING

After the plates were tacked, other welders laid the permanent weld. On the bottoms a weld the full thickness of the plates was used; but on the roofs a weld of 1/16 in. less than the thickness of the plates is sufficient; in other words, on 3/16-in. plates a 1/8-in. weld is sufficient.

Tests

A rigid inspection is given all work at the end of each day; anything looking like a pinhole is marked and rewelded. The bottoms are tested by pumping oil under the tank through fourteen flanges welded onto the bottom. On the second bottom welded at Texas City, only two pinholes developed, despite the fact that the bottom had been laid in very wet weather under the most difficult conditions; on the third bottom, only five pinholes developed.

The results on the first bottom showed well what not to do. In this case oil was run on the grade inside of the curbing before the plates were laid. Sloping horses, as shown in Fig. 7, were then placed across the center of the grade, and the plates dragged upon them, the intention being to weld two courses of sheets, drag the horses out part way, lay two more courses, weld those, and repeat the operation. Two difficulties presented themselves: First, it seemed impossible to lay the sheets without getting them fairly covered with oil; this, of course, made good welding quite difficult. Then, after the horses had been pulled out and the sheets rested on

the oil, the hot sun would tend to buckle the plates considerably; in addition, there was always the danger of fire, in fact one small fire did occur. Nevertheless, this bottom was finished by this method. It showed a great many buckles and developed about 100 pinholes; these were re-welded and when the tank was finally completed and tested, it showed no leaks.

FIG. 7—BOTTOM LAID ON A CRUDE-OIL FOUNDATION, USING SLOPING HORSES

The tests made by the Marland Refining Co. on the roofs at Tonkawa showed excellent results. Strips cut from the roofs through the weld transversely to the welded seam had an average tensile strength of 40,000 lb. per sq. in.; in other words, the weld was 72½ per cent the strength of the plate, using 55,000 lb. as the tensile strength of the plate. As the strength of the joint of a single riveted roof, using 3/16-in. plates and 7/16-in. rivets, is only 40.1 per cent efficient, the fear of weakness in a welded roof is completely dispelled. A photomicrograph of the cross-section of one of these test pieces is shown in Fig. 8.

Three bottoms and sixteen roofs were electric-welded during 1923, under the observation of the writer, Fig. 9. All of these tanks have been subjected to extreme changes in temperature, and to date there has not been a single evidence of failure. No cracks have developed and, consequently, no leaks. We do not mean that there have been no pinholes; there have been a few, and these were easily rewelded or calked. The welding of these tanks was done in the worst kind of weather. The heavy rains in Texas and Oklahoma have given the practicability of the work a test not contemplated when the work was started. Good welding cannot be performed on a wet surface; rains therefore delayed the work. At times, also, in Texas the dew was so heavy at night that work had to cease until the sun came up. Strong winds also caused trouble. One obstacle for which we were not prepared was the attraction

of bugs to the arc. Fortunately this would occur only on a very warm, breezeless night, but when it did the speed of welding was greatly reduced or welding ceased altogether, for the multitude of dead insects not only obstructed the weld, but proved very disagreeable to the welder.

Data

Records kept of all welding operations on the nineteen roofs and bottoms disclose the following average welding speeds: Roofs, 16 ft. per hour; bottoms, 14 ft. per hour; bottom angle to bottom plates, 4½ ft. per hour; tacking 70 hr. per roof or bottom.

FIG. 8—CROSS-SECTION OF WELDED-ROOF JOINT, SHOWING PENETRATION OF WELDING METAL INTO ROOF PLATE

Roof and bottom plates were of 3/16-in. steel, except the bottom sketch plates, which were ¼ in. Bottom angles were ⅝ in. thick and were welded to a height of at least ⅜ in. As stated, these figures are averages of all the welders; some men worked faster than others. At times under perfect conditions, speeds of 20, 25, and even 30 ft. per hour were made. On an 80,000-bbl. tank, there are approximately 2900 ft. of roof seam, provided 6 by 18 ft. plates are used; this size plate is readily handled. Should a smaller sheet be used there would be more footage, and the cost of the welded roof or bottom would naturally increase.

Machinery and Accessories

Both electric-driven and gasoline-driven welding machines of the direct-current type, with short arc characteristics were used

on this work. On the gasoline-driven machine, two shifts were used, working 18 to 20 hr. a day. On the electric-driven machines, three shifts were used, working 22½ hr. a day. We found the short arc of great advantage in assuring high-grade welding. It was necessary, of course, to use only the best welders. Many men who applied for work had been using long-arc machines. Some of

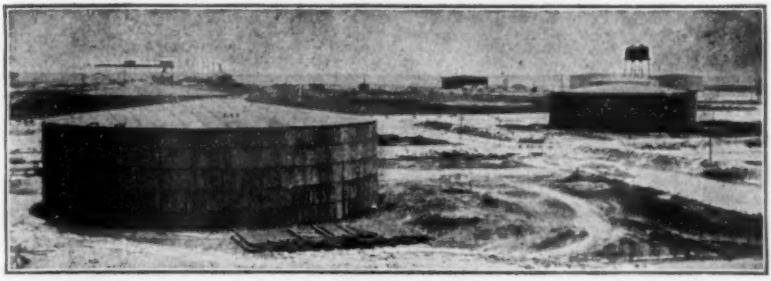


FIG. 9—NEW ELECTRIC-WELDED ROOFS ON OLD 55'S AT TEXAS CITY, TEX.

these, the poorer welders, were unable to operate with a short-arc even after being given considerable time to practice; the better welders, however, found no trouble in operating with the short arc after working 2 or 3 hr. Because of this we were never in fear of having poor welders on the job.

Several kinds of welding rods were tried, but we found that a coated rod of 5/32 in. diameter gave the best and most uniform results and warranted the small additional expense.

Advantages of Electric-Welded Tanks

The advantages of the electric-welded roof and bottom are:

1. As no holes must be punched, the plates can be shipped di-

FIG. 10—RIVETED ROOF

rect from the mill to the job without going through the shop for fabrication.

2. The bottom can be welded directly on the grade, thus eliminating the expense and time of placing the plates upon horses; the

usual working of the rivets and calking edges in the bottom, as it is being lowered, is also eliminated.

3. Sheets are much more readily fitted in place as there are no rivet holes to be matched.

4. The shell can be raised while the bottom is being welded, saving time in construction.

5. The one-piece roof expands and contracts uniformly with the

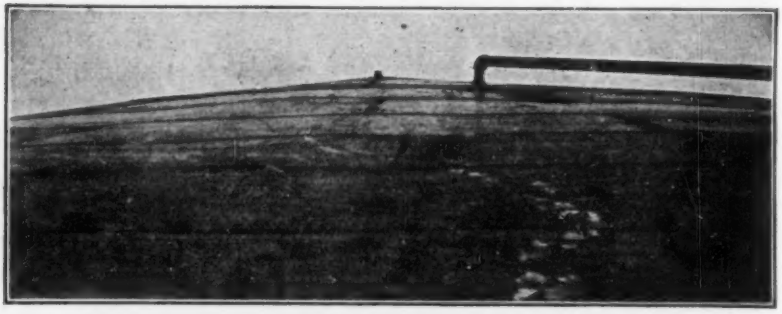


FIG. 11—WELDED-ROOF ADJACENT TO ROOF SHOWN IN FIG. 10; BOTH PHOTOGRAPHS WERE TAKEN THE SAME DAY AT SAME TIME FROM SAME LOCATION ON EACH TANK

change of the temperature, thus working of the rivets and calking edge as on a riveted roof is eliminated. This makes the roof absolutely gas-tight and greatly reduces the fire hazard; the cost of insurance should be correspondingly reduced.

6. The roof and bottom are smoother than by riveted construction, eliminating strains caused by buckling, Figs. 10, 11 and 12.

7. A welded joint should have longer life than a riveted joint; in nearly all worn-out bottoms, the rivets have been the first to go.

8. The welded bottoms, being one piece, are absolutely tight.

9. The cost of scaffolding under the roof for the use of riveters is eliminated; with a welded roof, it is unnecessary to have any one underneath, which is a great advantage in hot weather.

Future Applications of Welding

Naturally, the next step to be taken in tank welding will be the welding of the shell. One can expect to hear any time of this being attempted. The greatest difficulty in the welding of a shell will be in the assembling and tacking. A shell with the vertical seams welded inside and out should certainly develop a greater strength than one of riveted construction.

Another use for electric welding in tank construction is in the replacement of worn-out bottoms. Heretofore, where the bottom has been completely worn out, it has been necessary to build a concrete bottom or, if a steel bottom is desired, to tear down the tank, put in a new bottom and reconstruct it. By the use of electric welding, the tank can be cleaned, a sheet cut out of the first ring, new plates dragged inside of the tank, set in place and welded.

The sketch plates can be welded on top of the bottom leg of the angle iron.

The writer wishes to acknowledge the assistance of V. T. Moon, chief engineer of the Marland Refining Co., from whom was obtained the data relative to the tests made on the welded roofs; also the assistance and cooperation of the engineers and executives of the Chicago Bridge and Iron Works and the Graver Corporation in the developing of methods for the assembling of roofs and bottoms.

FIG. 12—WELDED BOTTOM, SHOWING SMOOTH CONDITION OF PLATES AFTER WELDING

Discussion

E. P. Jessop, New York, N. Y.—The Navy Department has been prevailed upon to put into its specifications the authorization to weld tanks completely. The 150,000-bbl. tanks recently erected in Portsmouth, N. H., have electric-welded roofs and bottoms; they did not weld the circumference.

It must be remembered that welding today is not the unreliable thing it was a few years ago. When properly applied the average welder using proper equipment and method, will average 90 per

cent strength in a joint, as against about 72 per cent for treble riveted, 64 per cent for double riveted and from 30 to 40 per cent single riveted. The strength is controlled by the ductility much more than by the tensile strength. You can get tensile strength easily, but ductility is a measure of the ability of the equipment used and of the operator to handle the metal; in other words, it is a metallurgical condition. It is possible almost to destroy the material and still get almost full tensile strength on a test, but the metal is crystal hard and will stand no vibration or buckling and would be practically useless in the oil industry. With the short arc, as described by the author, you get a ductile metal and, at the same time, full strength. He used only a ⅛-in. weld on his roof and yet had plenty of strength; no matter how much additional metal he would have added, he would have gotten little more strength because welding at the joint fuses the two pieces together and the greater part of the strength comes through this rather than through the amount of welding material added to the outside. The waste of welding wire is great because people believe that the more metal is put on a joint the stronger is the joint. If laid in with the proper method sufficient welding metal is about half the fillet on a double-welded joint. But even less than that may be used and still decrease the strength very slightly, as the two plates are fused together by the arc in addition to having the welded material there.

But the point is that if a welded joint is two-thirds stronger than a riveted joint, or one-third stronger, as the thickness of the metal in the tank is determined by the fact that the single-riveted joint is only 50 or 60 per cent efficient, usually nearer 50 than 60, it is possible to save 25 per cent of the material on an all-welded tank and get a stronger tank and one that is gas-tight. So that welding, in the oil industry, gives three things: Lighter tanks, if you want them; gas-tight tanks, and tanks that require practically no upkeep. These three things make welding the natural method of assembling tanks that are assembled for permanence and not for just over night.

H. A. Wheeler, St. Louis, Mo.—How about the cost?

E. P. Jessop.—The cost is very nearly the same as the riveted cost. At Portsmouth I think the contract price was $70,000; we estimated that between $700 and $1,000 would have been saved if the entire tank had been welded. But original cost is a lot less important than it seems to be. A welded tank is a so much better tank that it will save you money in the long run; it is gas-tight.

H. A. Wheeler.—You do not rivet the vertical shapes?

E. P. Jessop.—I would weld the whole thing, but I would not let an unskilled man do it. It is possible to get 100 per cent strength in a welded joint, but the average joint will run probably between 85 and 90.

H. A. Wheeler.—How about burning the riveting steel?

E. P. Jessop.—The equipment enters into that. Burned steel becomes evident right away to any engineer that is on the job. They burned some plates on the tanks in Portsmouth but the fact was so apparent that a novice could see it. Visual inspection will tell you that. People say it is not possible to test a welded joint; you can test it the same way as a riveted joint.

The reason I am so sure of what I say is that in 1917 we did $273,000 worth of welding on the German ships in the Port of New York and not one of those welds has gone bad. They are all electric-arc welded. But any company that is planning to do this work on a big scale should have in its employ some one who knows welding; you cannot do it carelessly.

H. A. Wheeler.—Is the welding metal a high-carbon steel?

E. P. Jessop.—Its composition depends on the kind of work you are doing. The metal in this work would be a steel that would run strong in manganese so that, after going through the arc it would still have sufficient manganese to give it the proper toughness. It is also high in carbon.

SHOP PRACTICE ON THE SANTA FE*

H. A. PATTERSON†

Every standard welding operation performed in our shops is covered by specifications as contained in our welding folio. If we apply a new crown sheet to a firebox our folio shows us the number of inches our weld must be from the highest point of the sheet. It tells us the electrode best suited for the job and recommends an approximate current value for this class of work.

While circumstances somewhat alter cases, this folio is a constant guide and advisor in all our work. If some shop foreman requests a flat spot on a driving tire built up and our folio contains a paragraph forbidding this operation, we can refuse and have something to back us up. In other words, it explains to us that which our officials and engineers want, and thereby we strive for results according to their plans and desires and our own mechanical ability.

All of our welders are compelled to make monthly test plates. These plates are tested and analyzed and the welder informed of his progress.

I have recently read with much interest in the Journal of this Society and other publications, some wonderful and speedy operations that certain men claim they have accomplished in arc welding with a large electrode and a high current value. Now, on my first introduction into the great field of electric arc welding several years ago, we used for filler rods strips of sheared boiler plate, 3/8-in. round wrought iron rolled steel bars used in automatic screw

*Presented before the May, 1924 meeting, San Francisco Section, A. W. S.
†Forman Welder, A. T. & S. F. Ry.

and other machines——in fact, mostly anything we could salvage from the scrap pile or otherwise. Later developments led us to settle on a ¼-in. American iron rod manufactured primarily for the oxy-acetylene flame, and I can vividly remember using a current value as high as 350 amp.—a soft iron welding rod 36 in. in length; and the operator held the electrode holder—a big, cumbersome tool, in both hands, as if it might be some tool of torture. Later developments reduced the diameter of our rod to 3/16 in., and today our welding folio shows no specifications calling for a welding rod larger than 5/32 in. or a current value of much over 150 amp.; and we are doing pressure welding on locomotive boilers with a low current value, ⅛-in. and 5/32-in. electrodes, maintaining our high standard as to quality of weld and character of workmanship, which would be impossible to accomplish with 3/16-in. and ¼-in. electrodes. In this connection let me emphasize that in the railroad shops today we are just as keen on shop output and production costs as those who operate contract shops, and we must produce results that will satisfy our own and Government inspectors and stand up under hard and sometimes unfair usage and to do all this it must be right.

As most of you no doubt know it has been for years our standard practice to weld all our boiler flues to tube sheet on firebox end. This is accomplished by expanding and beading the flue in the usual manner; then welding flue bead tight to the sheet by depositing a layer of metal around flue, equally distributed between the flue bead and sheet. While this operation has lengthened the time between flue removals the body of the flues has been found to contain a greater amount of pits. This can possibly be accounted for because on certain districts where before welding we got from 8 to 18 months' service out of a set of flues, they now go from 36 to 48 months before resetting is necessary, and while this pitting is easily handled by building up the pitted spots, I believe this is an interesting by-product of welding development.

In our shop considerable loco frame welding is done. This operation, when properly performed, is a big money saver for all concerned. We have one class of engine that is a chronic frame breaker in a certain section, and this break always occurs at a point where it is impossible to reinforce if welded. Now, if due to some peculiar strain or some unknown condition that causes fatigue of the metal at this given point, it is only with difficulty that the parent metal is able to withstand this strain, it should be impossible to expect a fusion weld that cannot even so much as be reinforced to hold in this same said section. Now, to overcome this difficulty, we cut out a section of the frame and replace it with a carefully annealed steel patch, bringing our welds back to a point where they can be reinforced, and what our weld lacks in quality we make up in quantity.

Perhaps some of you have been employed in a railroad round-

house and if so, you can recall the amount of time and energy that was spent in renewing bolts around the machinery on locomotives as the continual strain and stress of the engine would eventually loosen them. When an engine is received in the shop now for general repairs the frame splice bolts, guide yoke knee bolts, frame x tie bolts, tail piece, chafing iron and many others are removed, the holes carefully reamed, new bolts fit to hole and carefully cinched up tight; then, in addition, these are welded securely to engine frames, thereby eliminating considerable running repairs that the mechanic of yesterday did not consider would ever be accomplished.

To some men not familiar with railroad work, it might be interesting to enumerate a few of the welding and cutting operations applied to one of our locomotives undergoing general repairs:

300 rivet heads burned off.
900 stay bolts burned out.
100 ft. of ⅜-in. boiler sheets burned.
Welding in new crown sheet—total welding feet 24.
Two mud ring corner patches welded—36 in.
Two half side sheets welded—248 in.
Front flue sheet patch welded—48 in.
Back flue sheet patch welded—72 in.
Bottom section of smoke box welded—96 in.
220 flexible stay bolt sleeves welded to wrapper sheet.
Two 20-in. patches welded in locomotive frame (4 welds).
200 pitted flues built up.
150 oversize stay bolt holes plugged in wrapper sheet.
320 flues welded to tube sheet.
Six D boxes brass fit and saddle seat built up.
Worn valve gear parts built up.
Six brake hangers built up.
Set of spring equalizers built up.
Engine truck rails welded to center casting.
Chafing iron built up.
Frame x welded ties to frames.
Guide yoke knees welded to frames.
Spring pocket built up.
Coupler casting welded.
Coupler yoke built up.
Two truck bolsters and frames welded.
Patch in tank side sheet welded.
Set of rod brasses built up.

Two brasses built on boiler head for water glass fittings and innumerable smaller jobs, such as plugging holes, brazing pipes and cutting different parts to fit.

Another subject that must be seriously considered by all railroads and others doing similar work, unless the welding progress is to be retarded, is that of annealing, and I would like to emphasize

that by saying careful annealing. When fusion welding was first adopted it filled such a long-felt need that there was a great sympathetic feeling extended it. However, as it became a standard practice, such as any other shop operation, and failures occurred and research work began it soon was discovered that great structural changes were perceptible in the parent metal when these welding operations were being performed. This finally led to the prohibition of welding operations on certain parts by some railroads, such as pistons, x heads, crank pins, tires and other miscellaneaous and heat-treated parts. These structural changes likewise take place on numerous freight car castings and most large railroads are now making provision for annealing furnaces, which, with some modification in the A. R. A. rules covering interchange, will open another big welding field in the reclamation of freight car castings.

In conclusion I wish to state that the great trend of the welding developments today is to speed up the operations. Let us do all we can along this line, but let us not sacrifice quality and character of workmanship for speed.

Standardization of Practice in Demolition Work

T. C. FETHERSTON

Standardization of oxy-acetylene welding and cutting practice is usually thought of in connection with oft-repeated production operations.

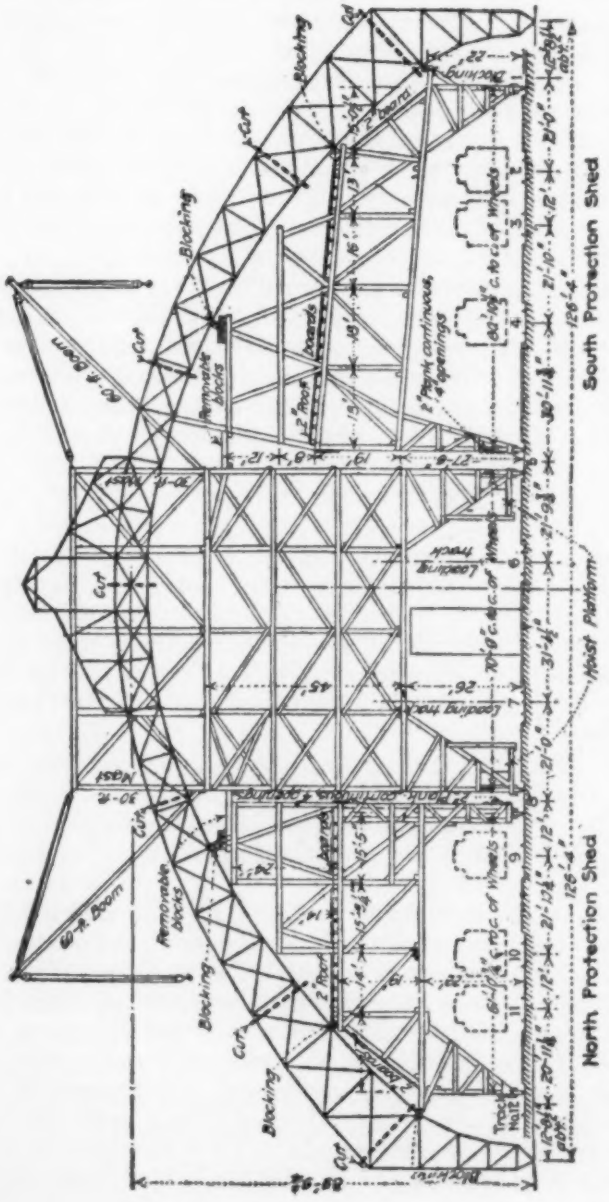
Instances have come up, however, where a careful study of an oxy-acetylene operation performed once only has enabled the user of the process to standardize his practices for this operation so that when another application of the same kind confronts him he can apply the program built up for himself in the earlier work. A study of the oxy-acetylene process from this angle results in great economies in applying welding and cutting, and makes possible large undertakings which might not be immediately practicable if the experiences on previous jobs of similar nature were not recorded and catalogued.

An instance aptly illustrating this point is the manner in which the work of dismantling the train shed at the Pennsylvania Railroad's Broad Street Station in Philadelphia was handled after the roofing was destroyed by fire several months ago. Fortunately the steel arches forming the main skeleton did not collapse.

A first thought that came to many engineers upon reading of the fire concerned the manner in which the ruined frame would be removed to make way for a new structure. It was conceded that oxy-acetylene cutting would be employed to reduce these great arched girders to size for convenient handling, but the real prob-

lem concerned the methods of applying the cutting blowpipe to this immense demolition job.

It happened that the contract for removing the train shed skeleton was secured by the same prominent Eastern concern that had taken down the train shed at the Jersey City Terminal of the Pennsylvania Railroad a year previously. As the work on this job had progressed these people had standardized their oxy-acetylene op-



System used in the demolition of train shed at the Pennsylvania Railroad's Broad Street Station in Philadelphia

erations to pure routine. This gave that contracting firm the "inside edge" on the job, and when the reduction of the Philadelphia train shed to handling size was undertaken it was only necessary to adapt the practices standardized for the Jersey City work to the larger sized job at Philadelphia. The latter shed was broader, taller and a considerably larger amount of metal had to be handled than at the Jersey City job, but the same practices proved correct in one instance could be applied in the other.

At both places it was necessary that the work be carried on without interfering with passengers using the station and with as little interference with traffic as possible. Accordingly it was so arranged that sections of the shed could be taken down progressively. Cranes, blocking supports and protection roofing were made movable so that these could be set up under the place where the actual demolition was being carried on. When one section was removed the cranes and the scaffolding could be moved on so that the next section could be attacked.

In general the equipment used consisted of a main traveler and two sheds, one on each side, to protect traffic below. These three individual units were mounted on wheels and traveled on certain of the tracks which of course were closed to train operation.

The main demolition platform in the center was fitted with two derricks, these working from opposite sides and so arranged that they could swing the sections as cut down from their position into cars waiting on two tracks below, reserved for this work.

The protecting sheds on each side of the main demolition platform were fitted with shoring to support remaining members of the train shed arch after the sections above had been removed. The first cut in each section was made through the center of the arch after the arch was braced in three or four places. Two cuts were next made approximately a car length from the center on each side and the two sections now free were swung down to the freight cars waiting below.

What was left of the arch after these two sections were removed would now rest on the shoring built up on the protecting sheds. Two more cuts were made about a car length farther down toward the base of the arch and this continued until an entire section was removed.

As each unit was disposed of in this way the cutting work proceeded to the next point until the limit of operations of the traveler and the protecting sheds was reached. Then this equipment was moved forward to where the demolition work could again begin.

With the work standardized in this way the enormous task of taking down this train shed proceeded smoothly and rapidly. Careful planning based on previous experience had forestalled unforeseen interruptions in the work. This, of course, made for promptness, and by keeping down the length of time necessary to complete the job, materially reduced the cost of the entire operation.

OXYACETYLENE WELDING OF NON-FERROUS METALS*

By Alfred S. Kinsey†

The oxyacetylene torch by its use of the principle of fusion can weld all of the non-ferrous metals, and such work is being done every day in many shops. In some instances, however, it is probable that better welds could have been made had the welders understood more thoroughly the practical metallurgy of the metals. It is fair to assume that in most cases oxyacetylene welders already know the simple steps to be taken in the actual welding of the non-ferrous metals, but there is reason to believe that such information as may be supplied in addition to that already available regarding the effect of welding on the chemical and physical characteristics of these metals may prove of help.

There are certain variables in the heating and melting of non-ferrous metals which have at times proved puzzling to welders. Also the chemical composition of such non-ferrous metals as are supposed to be alike are sometimes quite different, while frequently metals called by the same name, like *brass,* have a wide range of proportions of chemical ingredients which materially changes their physical nature.

The Metal Groups

The common metals of shop practice are divided in two groups known as the Ferrous and the Non-Ferrous metals, the word *Ferrous* being Latin for iron. The ferrous metals depend on iron as the base, while the non-ferrous metals usually have as the principal base metals copper, aluminum or nickel. Typical metals of the two groups would therefore be

Ferrous (Iron) Group	Non-Ferrous (No Iron) Group
Cast Iron,	Copper,
Malleable Iron,	Brass, Cast,
Wrought Iron	Brass, Rolled or Drawn,
Low Carbon Steel,	Bronze, Cast,
Medium Carbon Steel,	Bronze, Rolled or Drawn,
High Carbon Steel,	Lead,
High Speed Steel,	Tin,
Alloy Steel.	Zinc,
	Aluminum,
	Nickel.

The non-ferrous metals differ greatly in chemical composition and physical characteristics from those of the ferrous group. The

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irons and steels are the metals used chiefly for strength, while the non-ferrous metals are of service principally because of their non-rusting, acid resisting, heat conduction qualities. The non-ferrous metals are also much used as castings, which may be of light weight and capable of withstanding frequent expansion and contraction. They are also produced in the rolled or drawn condition, which

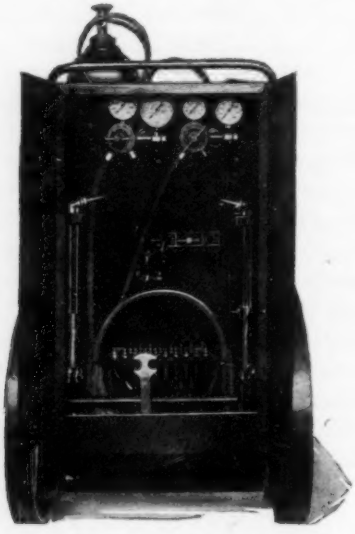

Fig. 1—Typical Welding Plant for Welding Non-Ferrous Metals

makes them several times stronger than the castings, due to the fact that the grains are finer and closer together. The non-ferrous metals are used in many instances because they are much softer than the ferrous metals and more easily shapened and finished by hand or machine. They have lower melting points than the irons or steels, and therefore may be made into castings more readily and at less expense.

PART 1. COPPER

Melting Copper

This is the base metal of all the brasses and bronzes, and is used in varying quantities in many other metals. A welder who has not had experience with copper will find that it possesses several important physical characteristics when being heated which are quite different from the metals of the ferrous group, such as (a) The absorption of dissolved oxides by the molten metal, (b) The hardening and annealing of the metal and (c) The high rate of conductivity. And there are other interesting things about copper which a welder should know.

The melting point of copper is about 1950 deg. Fahr. When the metal is heated to this temperature certain peculiar chemical

changes occur. Oxygen from the air unites with the copper when the metal first melts and forms Cuprous Oxide (Cu_2O), the word Cuprous meaning *copper*. Then as a result of the formation of cuprous oxide another oxide is produced known as Cupric Oxide (CuO). If the copper contains sulphur there will also be formed two sulphides, the first being called Cupric Sulphide (CuS), which is more likely to be found in the copper ore, and later in the process of refining Cupric Sulphide (Cu_2S) may show itself. Both of the oxides and of the sulphides are undesirable in copper, but it is impossible to melt the metal under ordinary conditions without the formation of some of these impurities.

While oxides in the irons and steels usually remain in the form of small solid particles between the flat-sided grains, the oxides of copper have the characteristic of melting and being absorbed by the molten copper, which makes them quite difficult to remove from the metal, and then after the copper becomes cold and solid the oxides which remain form between the grains and retard their sliding action, with the result that the copper becomes brittle and hard when cold.

Therefore, if copper is melted, as for example, in the making of a weld, it is quite essential that the oxides should be removed from the molten metal before it solidifies. In some metals this could be accomplished by the introduction of a powdered flux into the molten mass, which works satisfactorily because the oxides lie as a slag on top of the pool, but in the case of copper the oxides are *absorbed* by the metal and cannot be reached by the ordinary powder flux. They must, therefore, be removed by another method.

Phosphorus is the best deoxidizer of copper. It has a strong tendency to destroy the dissolved oxides. But it must be deposited in the metal in such a way that it will be distributed thoroughly throughout the molten mass. It is, therefore, possible to put phosphorus into molten copper in the form of a phosphorus—copper alloy, like in a copper welding rod, in which case the phosphorus is released as the rod melts and distributing itself through the molten copper it combines with the oxides and releases them so that they float to the top of the pool and form as a slag covering, thereby protecting the molten metal from the oxygen of the air. The phosphorus in the slag has been changed while in the melted copper, to phosphoric acid, which has the nature of absorbing the oxygen of the air, and thereby reducing the first source of the oxidation. Copper welding rods are therefore made to contain a sufficient amount of phosphorus to serve as the deoxidizer of a copper weld instead of a powder flux.

It does not require much phosphorus to deoxidize copper, the amount in welding rods usually being a little less than 1 per cent. This, however, as already explained, would be too much to be left in copper after it had become solid and cold, as a quantity even as high as 0.5 per cent will make copper red-short.

A copper weld if properly made with the oxyacetylene torch will have fluxed off the phosphorus sufficiently to avoid any danger of red-shortness or brittleness, and this combined with the non-oxidizing, neutral atmosphere of the oxyacetylene flame makes it a successful means of melting and welding copper.

Hardening and Annealing Copper

When tool steel is to be hardened it has but to be heated to a red and quenched in cold water, but in copper that would produce the opposite effect, as that is the way to anneal that metal. Copper cannot be hardened by heat treatment, the grains must be squeezed or jarred together by mechanical treatment, such as rolling, drawing or hammering, or some kind of an alloy must be mixed with the molten copper. It is easy, therefore, to harden a piece of sheet copper by merely hammering it and to anneal it by heating to a red and quenching in water or letting it cool in the air. The hardening of copper has a beneficial effect on its strength, for a piece of annealed copper having a tensile strength of about 20,000 lb. per square inch will have that figure increased to about 30,000 lb. by hardening, and at the same time the elongation will remain as high as about 30 per cent. In the working of cold copper it sometimes becomes hardened before the work is completed, and it may be necessary to anneal the metal several times. This has no detrimental effect on the copper.

Conductivity of Copper

When heat is applied at a particular spot on a piece of metal it immediately spreads throughout the mass, traveling much faster through some metals than in others. This conduction of the heat is affected chiefly by the chemical nature of the metal, the carbon in cast iron, for example, retarding the rate of conduction, called the *Conductivity*, so that it is only about one-ninth that of silver. The conductivity of copper is next to the highest of all the metals, being 89 as compared with 100 for silver and 11 for cast iron. This is of good advantage to copper in many instances where the metal in the hard sheet form must serve, say, as a vessel for holding hot liquids, but when it is necessary to melt the copper in order to weld it, the high conductivity makes the work more difficult. It therefore requires a large volume of heat applied quickly to the joint to be welded in order to melt the metal under proper conditions, and this is readily accomplished by the oxyacetylene flame with its unusually high temperature of about 6300 deg. Fahr. A welding tip is used for copper about two sizes bigger than that for steel of the same thickness of welded metal.

Granular Structure of Copper

A piece of copper is formed of flat-sided grains, each grain being composed of many crystals. The crystals are somewhat like a

tree, with stem and branches and are sometimes called *Tree Crystals.* The long stem centers point toward an outer surface of the grains and the branches of adjoining crystals interlock. When the metal is heated the crystals slide apart and the whole grain is enlarged. This is called *Expansion.* In copper the size of the

Fig. 2—Copper before being Welded, Magnified 175 x

grains may increase as much as ten times, from a diameter of, say, 0.0005 in. when cold and rolled or hammered, to 0.005 in. when heated. When a piece of hot copper is allowed to become cold the crystals slide together, thereby decreasing the size of the grains and reducing the dimensions of the whole piece of metal. This is *Contraction.* But the crystals will not go all the way back to their original positions, due to the amount of oxides which get between them and the grain surfaces and interfere with their sliding action. This interference is not as serious in copper as in steel, and it may be made still less by hammering the copper as it cools. Therefore every time a piece of copper is heated to a red and allowed to cool

its dimensions are permanently increased, and many heatings will gradually enlarge the piece of metal. This is called the *Growth of Metal,* and if carried to the extreme it would spread the crystals and grains apart so that they would lose much of the power of cohesion which holds them together, and the metal might break

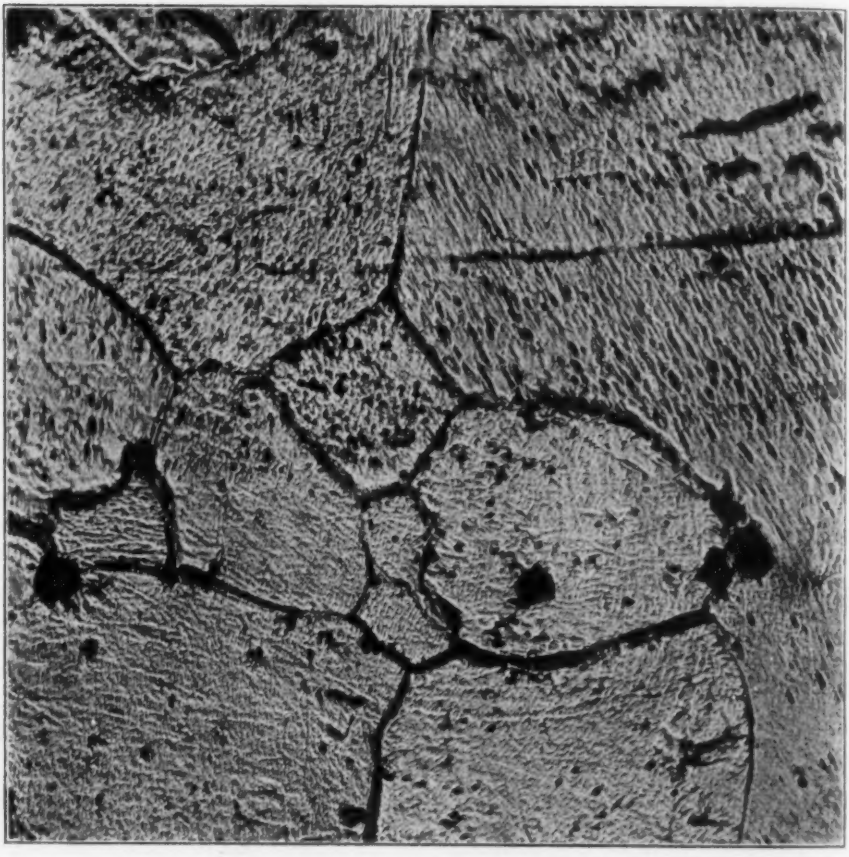

Fig. 3—Copper after being Oxy-acetylene Welded, Magnified 175 x

from this growth or permanent expansion. Oxyacetylene welders should always try to complete a weld with as few reheatings as possible.

Welding Copper Plate

Some interesting information has been obtained from the welding of some big cylindrical sections of 5/16-in. and ⅜-in. copper plate: (1) In the longest welds, about 45 in., the non-rigid method was used, that is, the edges were diverged and later allowed to close from expansion. The rate of divergence was ½ in. per foot for the first 8 in. and double that for the remainder of the weld,

which was required by the increased rate of expansion. (2) Preheating of this long seam was necessary and it was accomplished by a kerosene burner projecting a flame along under the joint through a trough-shaped flue which confined the heating to a width of about 4 in. each side of the weld. This restriction was used in order to prevent unnecessary annealing of the cold rolled copper. (3) The best welding rod for the long copper seam proved to be a copper rod containing a small percentage of iron. In another part of the work where the copper weld had not only to be tight, but also of high shearing strength, a stronger welding rod was necessary, which was composed of copper and a small amount of phosphorus. (4) In certain parts of the job steel 5/16 in. thick had to be welded to the copper. The steel heated quicker than the copper, and the copper cooled quicker than the steel, which made the welding more difficult, but it was successfully done. The best welding rod for this proved to be the standard tobin bronze rod, used with the regular flux sold for welding copper. (5) In another part of the job brass castings had to be welded to the copper plate and this was satisfactorily done by using tobin bronze rod. The greater expansion and contraction of the copper plate made it necessary to increase the thickness of the weld in order to overcome its tendency to crack. (6) Some of the information gained about copper welding rods was—(a) That an Iron-Copper rod is best *for tightness* of weld. (b) That a Phosphor-Copper rod should be used *to resist rubbing wear.* (c) That Tobin Bronze rod is best for welding *a non-ferrous metal* like copper *to a ferrous metal* like steel. (d) That Manganese-Bronze rod should be used *for strength* of weld. (e) That Silicon-Copper rod is good for a copper weld which may have special tendencies *to oxidize.*

PART II. BRASS

Composition of Brass

It is said that there are about 2500 possible alloyed brasses, 50 of which are being produced by the brass mills, and it is therefore apparent that it would be difficult for an oxyacetylene welder to guess the chemical composition of any particular piece of the metal. Brass is not a natural ore like copper, it is a composite metal made with copper as the base and by alloying it principally with zinc, tin or lead. There are two principal kinds of brass, one being made by melting the metal and pouring it into molds to give it its shape. This pouring is called *Casting* and the metal is therefore called *Cast* Brass. The other kind of brass is made by running the metal through heavy rollers or by drawing it through dies, from which is derived *Rolled* or *Drawn* Brass. The principal

chemical difference between cast brass and rolled brass may be seen in the following typical analyses:

Rolled Brass (Yellow)		Cast Brass (Red)	
Copper	60%	Copper	85%
Zinc	40	Zinc	5
		Lead	5
		Tin	5
	100%		100%
Tensile Strength	50,000 lb.		35,000 lb.

Rolled brass is usually called *Yellow* brass because of its yellowish hue, and cast brass because of its reddish shade is known as *Red* brass. It will be seen, therefore, that simply by varying the percentage of copper and the alloys a great variety of brasses may be obtained, applicable to practically any service ever required of the metal. It also will be apparent that an oxyacetylene welder would notice quite a difference in melting brass because, for example, there is a much greater percentage of zinc in rolled than in cast brass, and in cast brass there are the additional peculiar characteristics of lead and tin to influence the welding of the metal.

Rolled and Drawn Brass

By rolling or drawing an ingot of hot brass the metal is made in the form of rod. wire, sheet or tube. Rod and wire are made by forcing a hot brass billet against holes in a die of a machine by hydraulic pressure, the soft plastic metal being thereby pushed through the holes and coming out as rods. This is called the *Extrusion* method. The rods are then *Drawn* through dies, which is the opposite of being extruded, after which they are ready for use. On the other hand, brass tubes are made by forcing a hot brass billet over the end of a pointed steel rod until it has been formed like a long thimble. The closed end of the thimble is then crushed to a point which is pushed through a die gripped by a drawhead and drawn the full length. It requires a number of drawings to get the tube to final dimension, and there are many shapes to the tubes. Sheet brass is made by running cast flat bars through milling machines in order to remove the rough surfaces and then rolling the clean cast bar repeatedly until reduced to the desired thickness. The drawing and rolling of brass hardens it so that sometimes it is necessary to frequently anneal the metal while it is being finished to size. In fact brass is tempered by the pressure of rolling or drawing which forces the grains closer together. There are three *Tempers* which are definitely recognized, known as *Quarter Hard* when reduced on the last rolling 10 per cent in thickness, *Half Hard* when reduced 20 per cent, and *Hard* when reduced 40 per cent in thickness. Hardened brass is annealed by

heating it to certain temperatures and quenching it in water. There are three recognized degrees of annealing, known as *Light Annealed* when drawn at 500 deg. C., *Soft* when drawn at 600 deg. C. and *Dead Soft* at 700 deg. C.

Cast Brass

A brass casting is made by melting and pouring the metal into a sand mold. This changes the physical but not the chemical nature

Fig. 4—Brass before being Welded, Magnified 175 x

of the metal, a brass casting being of weaker grain structure than rolled or drawn brass. This is due to the fact that in forming a brass casting no mechanical assistance is used to force its grains closely together, as occurs in the making of drawn or rolled brass. Therefore cast brass is weaker in tensile strength in the ratio of 35,000 lb. per square inch for cast brass and 50,000 lb. for rolled or drawn brass. Cast brass is also liable to have oxides form between the grains when the casting is made and these must be con-

sidered when the metal is melted again as in the making of an oxy-acetylene weld. It is plain to be seen, therefore, that an oxyacetylene welder may experience much more trouble in getting a good weld on one brass casting than on another and because of the variety of drawn and rolled brasses he may have a similar experience with that metal.

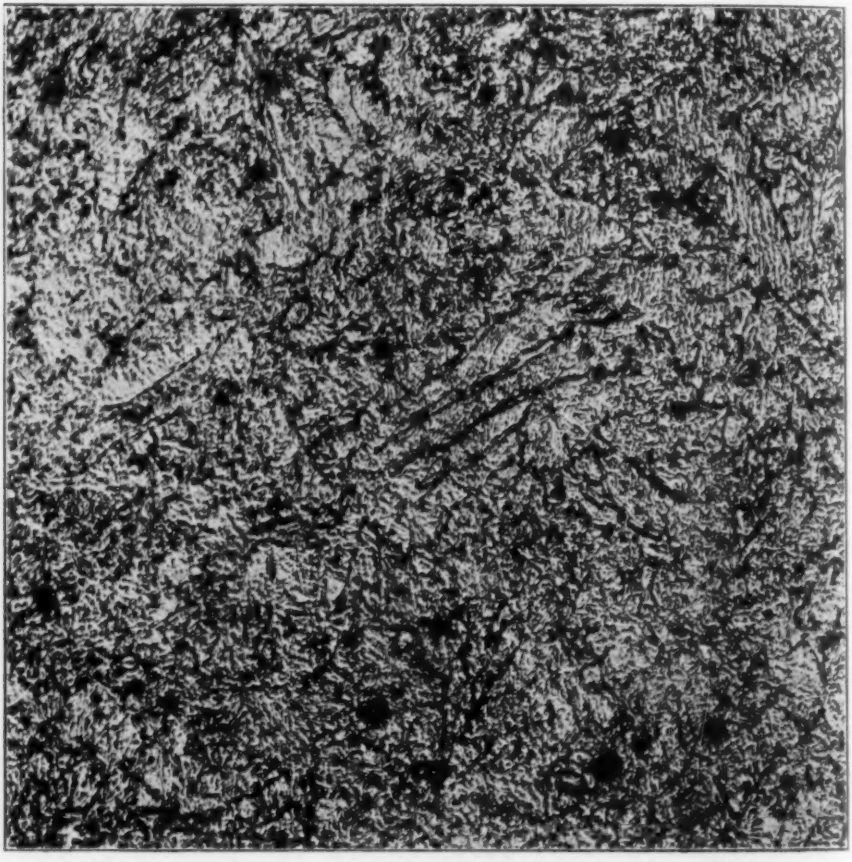

Fig. 5—Brass after being Oxy-acetylene Welded, Magnified 175 x

Alloys of Brass

Welding brass is influenced by the alloys of the metal, these being principally lead, tin and zinc. Lead has an interesting influence on brass. In the first place it does not combine with the copper base metal, that is, it does not locate itself in between the small crystals of each grain of copper, but lies in films or globules between the flat-sided grains. This pushes the grains apart so that the cohesion which holds them together is weakened and the whole piece of metal is lowered in tensile strength. This is principally

why the proportion of lead used must be carefully considered. On the other hand, the lead is of an advantage to brass in that it makes the machining of the metal more successful. That is, pure brass is hard to turn, therefore lead is added which locates itself between the grains of brass, and when the metal is turned the tool does not have to make a continuous cut of hard brass, but instead alternately cuts the brass and the lead, thus breaking the turnings into chips. Lead has another effect on brass, which is that it serves as a lubricant to the turning tool and thereby allows higher speeds of turning to be used. A common amount of lead used in brass is about 2 per cent, which added to about 60 per cent copper and 38 per zinc makes one of the most popular and serviceable rolled brasses in use. Tin is used to give brass its hardness and tensile strength, and at the same time it prevents the metal from corroding. Tin melts at 440 deg. Fahr., which indicates that soon after the oxyacetylene torch is applied to a piece of brass the tin will melt, and also would oxidize were it not for the neutral atmosphere created by the oxyacetylene flame over the molten metal.

Zinc in Brass

The presence of zinc in brass is made known to a welder by the white fumes which come from the metal as it is melted, and while the zinc begins to vaporize at a temperature at least as low as 780 deg. Fahr., it will boil off in a white cloud at 1725 deg. Fahr. This affects the composition of the brass and should be prevented by using a special welding rod. Welders will therefore realize the importance of using welding rod for brass which has been carefully selected and not chosen from scrap wire or rod of unknown composition.

PART 3. BRONZE

There are many different kinds of bronzes, all of which have copper as the base metal, as is also true of the brasses. Typical compositions of some common bronzes would be as follows:

	Machinery Bronze	Tobin Bronze	Manganese Bronze	Phosphor Bronze	Gun Metal
Copper	88	60	60	80	90
Tin	10	1	0.65	10	8
Zinc	2	38.50	38	..	2
Iron	..	0.20	1.25	..	..
Lead	..	0.30	.08	9.20	..
Phosphorus ..	..	..	..	0.80	..
Manganese ...	..	..	.20	..	..
	100%	100%	100%	100%	100%

Bronze is not as difficult to weld as brass, but care must be taken nevertheless to see that the welding metal is made to correspond with the particular kind of bronze being welded. For example, machinery bronze contains only about 2 per cent of zinc, whereas

tobin and manganese bronze contain about 38 per cent of zinc, while on the other hand there is 10 per cent of tin in machinery bronze and 1 per cent or less in the tobin and manganese bronzes. Special provision should, therefore, be made to take care of the oxides of zinc in the tobin and manganese bronzes which would not be true of the other bronzes. Of course it would be difficult for oxyacetylene welders to know the composition of any of the bronzes and a variety of welding rods might prove confusing to the average welder. It is, therefore, the practice to use a special welding rod to overcome the action of the copper oxides, especially where the amount of copper is as high as 88 or 90 per cent, as in machinery bronze and gun metal.

The comparatively high percentage of tin in machinery bronze and phosphor bronze will also have to be watched in welding these metals. Tin melts at 440 deg. Fahr., and therefore is easily overheated. This would vaporize it and by reducing its amount the tensile strength of the metal would be affected. The superheating of the pool of molten metal, therefore, should be avoided by keeping the tip of the incandescent cone of the flame from touching the metal. A flux should be used in the welding of the bronzes, of practically the same composition as that used for the welding of brasses.

Welders may find some help, when it is necessary to guess at the composition of the different bronzes, from the fact that each bronze has a peculiar adaptability to the use intended for it as a machine part or in some other form as may be seen in the following:

Machinery Bronze

As the name implies, this kind of bronze will be found as parts of machinery which must be strong and able to withstand corrosive action, say of liquids being passed through the machine.

Tobin Bronze

This is a metal of high tensile strength and will be found in use for structural parts like bolts, and machine parts which must withstand heavy loads and pulling strains. It is stronger than ordinary steel and has the additional advantage of resisting corrosion.

Manganese Bronze

The toughness of a metal is often its most desirable characteristic, and of the bronzes manganese bronze is depended on for machine parts calling for this requisite. Gears whose teeth may be strained and parts which may receive bending strains and otherwise depend on toughness, will often be made of manganese bronze.

Phosphor Bronze

A welder may expect to find this bronze in such machine parts as must withstand rubbing wear, Resistance to Abrasion as it is

called. Piston rods, piston rings, bearings, special shafting and many other metal parts which must endure a rubbing friction are most always made of phosphor bronze, and there is an interesting reason for this. As phosphorus combines with both copper and tin, it is usually put into the molten bronze in the form of the alloys phosphor-copper and Phosphor-tin. These act as deoxidizers to remove any oxides, and in doing so the oxide of phosphorus, being of an acid nature, combines with other metallic oxides in the molten metal and forming phosphates they become part of the slag and are removed. This leaves a clean metal which flows freely and is particularly adaptable to castings. Many of the best bronze castings are therefore of phosphor bronze. The phosphorus in bronze finally forms free oxides of copper, which give the metal the distinguishing qualification of being the best of all the bronze for withstanding rubbing wear. When phosphor-bronze is used as a machine part which is subjected to rubbing friction, the softer part of the metal wears away and leaves the surface formed of particles of hard phosphide of copper. Therefore the total friction of the wearing surface is reduced, and then borne satisfactorily by the hard phosphide. Also as the hard particles of phosphide of copper are embedded in and supported by the softer metal they can withstand severe shocks and much abuse before crushing out of place.

It may be seen, therefore, that to weld a bronze which must withstand severe rubbing wear with a tobin bronze welding rod having tensile strength as its principal qualification, would not give the most satisfactory results. A little study of this subject and some forethought would do much to help oxyacetylene welders produce more efficient welds of the bronzes.

PART 4. ALUMINUM

This is one of the most interesting metals to weld with the oxyacetylene torch. Its peculiar surface tension, its high rate of expansion and conductivity and its oxides all have proved to be problems worthy of the best efforts of a fusion welder. Aluminum is the lightest strong metal of common shop practice and its many uses give ample evidence of its value. Undoubtedly sufficient directions have already been given to guide welders in the handling of this metal and it will therefore be assumed that this chapter might better treat of the chemical, physical and mechanical properties of the metal as they relate to its welding.

Chemical Properties

Aluminum comes principally from two ores known as Bauxite and Cryolite, and it is used chiefly in the rolled or drawn or cast con-

dition. This should be understood by welders, for in the case of rolled and drawn aluminum there would be the copper alloy of the metal to consider, whereas in an aluminum casting the alloy would be zinc. Aluminum has a strong affinity for oxygen, as may be seen, for example, in its use as a powder in thermit welding metal. There are two principal grades of aluminum with the following chemical composition:

	No. 1	No. 2
Aluminum	99.55%	96.0%
Silicon	.30	2.0
Iron	.15	2.0
	100%	100%

Physical Properties

Aluminum melts at 1215 deg. Fahr., it expands more than most other metals, the rate being .0000130 for each degree Fahrenheit rise of temperature. This is twice as great an expansion as that for iron. It conducts heat faster than any other common shop metal except copper, iron having only about one-third as much conductivity. The specific gravity, that is, its weight compared with water, is 2.56 for aluminum castings and 2.68 for the rolled or drawn aluminum, that for steel being 7.9. The weight of a cubic inch of aluminum is equal to .096 lb., while that for cast iron is .260. The tensile strength for rolled aluminum is about 40,000 lb. per square inch and for cast aluminum about 14,000 lb. per square inch. Aluminum is the second metal in the list of malleability, gold being the first and aluminum is the sixth in ductility.

Aluminum-Alloy

There are two principal proportions of alloys used in aluminum, one with not more than 35 per cent of alloys and the other with about 85 per cent of alloys. In the first class the alloys are used to harden the aluminum, but in the second class the aluminum is the dominating metal and imparts important qualities to the alloys. The second principal group of alloys used in aluminum are copper and zinc, copper being the alloy for the rolled and drawn aluminum, and zinc the alloy for aluminum castings. In the case of copper as an alloy it is used in quantities up to about 15 per cent copper, and it is also to be found in another kind of aluminum in which the aluminum is reduced to about 10 per cent. The aluminum copper alloys have a tensile strength of about 20,000 lb. per square inch. When the alloy is increased and the amount of aluminum is less than 11 per cent the tensile strength may run as high as 110,000 lb. per square inch. Zinc gives a strong aluminum alloy, the tensile strength running as high as 40,000 lb. per square inch. When from 10 to 14 per cent of zinc is used the metal

is specially tough and malleable. Manganese is used as an alloy in aluminum in order to make the metal hard and strong, although these qualities are obtained at the expense of the ductility. Aluminum-manganese alloy also has a high resistance to corrosion. Tin serves as an alloy for aluminum, producing a stronger metal when it is used as a casting and also reducing the shrinkage of the metal.

Fig. 6—Aluminum before being Welded, Magnified 175 x

Nickel is sometimes used as an alloy of aluminum to give special hardening qualities to the metal.

Welding Principles

Some welders prefer to weld aluminum by the use of a flux, while others believe in the puddling method. Good work can be done both ways. If the flux is used care should be taken to see that it is not applied in excess and that it is completely removed after welding. Although the flux for aluminum is intended to react on the aluminum oxide, any grease or dirt on the metal may not

be properly removed if it depends on the action of the flux. When the puddling method is used there is greater likelihood of the complete removal of the oxides of the aluminum. As aluminum is likely to be hot short at about the welding temperature, the welding should proceed without delay and the temperature kept as constant as possible. The proper cooling of a completed aluminum weld is

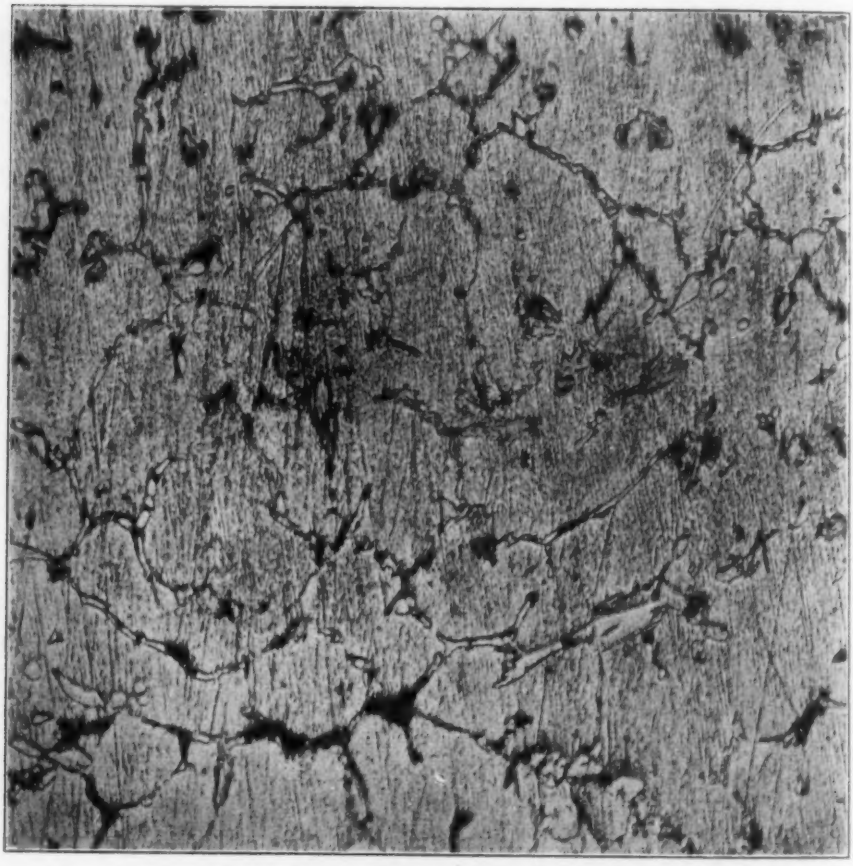

Fig. 7—Aluminum after being Welded, Magnified 175 x

quite essential, asbestos being a good insulating material to protect the hot metal from the air. It is well to keep in mind that as aluminum cools from its hottest liquid condition down to the point where it freezes the contraction is equal to about 3.5 per cent. The solid metal shrinkage from the freezing point on down to the temperature of the air will cause an additional contraction of about 1.3 per cent. It will, therefore, be seen that this comparatively large amount of contraction should be under proper control. If it is not, shrinkage cracks, metallurgically known as *Slip Bands*, may form no matter how perfectly the weld may have been executed.

PART 5. DURALUMIN

Chemical and Physical Properties

The chemical constituents of duralumin are:

Aluminum	95.0%
Copper	4.0
Manganese	0.5
Magnesium	0.5
	100%

The chief qualifications of duralumin are its high tensile strength which may amount to as much as 60,000 lb. per square inch, and its ductility which shows an elongation of 20 per cent, combined with its low specific gravity of 2.81 as compared with 7.9 for steel. Its non-corrosive qualities are excellent, especially in resisting salt water. The metal has been used considerably for airplanes.

Welding Methods

The welding of duralumin is accomplished by practically the same methods as those used for aluminum. The regular aluminum flux may be used. The weld, however, should be thoroughly heat treated to avoid corrosion and to increase the strength of the weld. The metal should be heated in a salt bath at a temperature of about 900 deg. Fahr., allowing it sufficient time while in the bath to become heat saturated, after which the metal should be quenched in hot water. The readjustment of the granular structure of the metal occurs slowly and it should therefore be allowed, whenever practicable, to lie about three or four days before it is put to use. This is called *Aging* the metal. The welding rod should be of practically the same composition as the base metal.

PART 6. MONEL METAL

One of the latest additions to the non-ferrous group is the strong white metal known as Monel Metal. Its chief characteristic is a combination of resistance to oxidation and high tensile strength. These make the metal of special value for exacting conditions like those produced by superheated steam, salt water, high gas temperatures, acid action, alkaline solutions, rust, electrolysis, weather action, etc. By these signs it may be seen that the new metal has established itself in most of the metal working industries, and hence the fact that it can be oxyacetylene welded satisfactorily should be of importance.

Chemical Composition

A common analysis of Monel metal would show:

Nickel	67%
Copper	28
Other Metals	5
	100%

The unnamed elements are usually iron, manganese, silicon and carbon. It may therefore be seen that the characteristics of the metal should be about the same as those which might be expected of nickel and copper, that is, chiefly resistance to the erosive and corrosive action of steam, hot gases, chemicals, weather, etc.

Physical Properties

Monel metal looks like soft nickel, but has the tensile strength of tool steel running as high as 100,000 lb. per square inch. Its stretching qualities are greater than those for low carbon steel, the elongation being about 45 per cent, it will conduct heat about one-fifteenth as fast as copper, it has an electrical conductivity equal to about 4 per cent of copper, its melting point is about 2480 deg. Fahr., as compared with 2200 deg. Fahr. for cast iron. Its specific gravity is 8.87, that of steel being 7.9. Weight per cubic inch as a casting 0.319 lb., and for cast iron 0.26 lb. Weight per cubic inch rolled 0.323 lb., as compared with 0.283 lb. for rolled steel. It shrinks at the rate of $\frac{1}{4}$ in. per foot, whereas the shrinkage for cast iron is $\frac{1}{8}$ in. per foot. These figures therefore indicate that Monel metal has an unusually high tensile strength for non-ferrous metal, which should be considered in the selection of the rod used for welding the metal. A rod of low tensile strength, for example, would weaken the weld job. The elongation or stretching quality of Monel metal, amounting to about 45 per cent, is of special advantage in certain cases and the weld can be made in this metal without the loss of more than a small fraction of the elongation. As the heat conductivity of Monel metal is only one-fifteenth that of copper the heat from the torch flame is under better control than in the welding of copper. On the other hand, the higher melting temperature of 2480 deg. Fahr. for Monel metal as compared with 1950 deg. Fahr. for copper requires a concentration of a greater amount of heat in a given time from the welding torch. Monel metal is produced by casting, rolling or drawing, the tensile strength of the cast metal being about half that of the rolled metal.

Welding Monel Metal

All forms of Monel metal are being successfully welded with the oxyacetylene torch, and to emphasize the following brief suggestions will probably prove sufficient, as details of the actual welding operations are commonly known. (a) Because of the copper alloy the molten metal is susceptible to oxidation or carbonization, and the neutral flame of the torch is therefore the right one to use. The oxyacetylene flame will prove specially advantageous in the melting of the metal, as the metal is inclined to absorb the gases of the air. These gases have a tendency to work their way well into the molten metal, but are forced back to the surface as the metal cools. This leaves a surface of oxidized porous material on the metal, and when a weld is being made this condition should be

considered and avoided by increasing the thickness of the weld sufficiently to force the spongy metal outside of the limits of the weld, so that the strength of the joint will not be affected by it. (b) Oxides will form when the metal is melted for welding, and as these are chiefly due to the copper in the Monel metal there will be a tendency for the metal to dissolve its oxides and absorb them. It is advisable therefore to try to make the weld in one melting of the metal rather than to come back over the work after it has become solid. To repeat the melting and cooling of the weld metal is liable to entrap oxides at the different layers and thereby make the weld porous. (c) Because of the high rate of heat conductivity of the copper in Monel metal, the molten metal of a weld will cool quickly if exposed to the air. This will cause the grains to stop sliding before they have completely returned to their former position, leaving the metal in a porous and weakened condition and at the same time setting up unequal strains between the grains. It is, therefore, the best practice to cover the molten metal and allow it to cool quite slowly. (d) Monel metal castings, like all other castings, may have unequal strains between the grains due to the uneven rates of cooling of the hot metal. If in preparing to make a weld the heating of Monel castings is done quickly the strains are liable to be released in such a way as to cause small cracks in the castings. These would be what are known in metallurgy as *Slip Bands*, which are difficult to correct. (e) If the metal is thin its rate of heat conduction will be so rapid that it must be heated quickly in order to melt and fuse the metal. Therefore any interference with this speed of heating, like that which might come from oxides on the metal, will prevent the making of a good weld. A flux is therefore used on thin Monel metal in order to prevent any slowing down of the welding by the oxides. However a flux should not be used on thicker sections of Monel metal as it is likely to encourage the entrapping of the oxides and cause porous metal. (f) The high melting temperature of 2480 deg. Fahr. for Monel metal makes it quite practicable to be fused with other metals of shop practice. It may easily be welded with the ferrous metals which have nearly the same melting temperature and therefore can be brought to the molten state at practically the same rate of speed.

PART 7. NICKEL

Physical Properties

The melting point of nickel is 2640 deg. Fahr. It shrinks at the rate of ¼ in. per foot. Weight per cubic inch equals 0.319 lb. Specific gravity 8.84. Tensile strength of A nickel 99 per cent pure when annealed is about 70,000 lb. per square inch, and when hard from rolling it is about 100,000 lb. per square inch. Average elongation annealed runs about 40 per cent.

Forging and Annealing

Nickel can be forged if heated to at least 2100 deg. Fahr., and its acts better under hammer blows than when press forged. To anneal nickel it should be heated to about 1500 deg. Fahr., making certain that it is heated uniformly throughout, and then allowed to cool in the air for ordinary conditions, but it would be better to anneal it in a box to prevent oxidation.

Welding

It is not possible to forge weld nickel, because of the oxidation, but it can be successfully welded with the oxyacetylene torch. The job should be laid on carbon blocks, not on cold iron, or it might be placed on asbestos if powdered carbon is used in between. Beveling should be done. The tip should be at least one size larger than for steel. The flame should not be oxidizing in the least, and to make sure of this it should be made slightly carbonizing. It would be best to use a flux, which should be composed of the following:

Borax
Carbon
Magnesium
Manganese
Silicon

This is powdered and mixed in liquid shellac. The welding rod is usually of a D nickel containing a small percentage of manganese.

Metallurgy

The grains of nickel are flat-sided and similar to those of steel. The crystalline structure of these grains is quite sensitive to oxygen or sulphur, and if attacked by those elements the crystals will absorb them and thus stop the natural sliding action of the crystals so that the structure of each grain is stiffened or brittlized. The crystals will change their arrangement to such an extent as to show fine cracks on the flat surfaces of the grains and the metal is thus caused to lose its malleability and bending qualities. It will therefore be apparent to a welder that care must be taken to prevent oxygen from reaching the grain surfaces when the metal is hot and the crystals are slidden apart from expansion. Very likely the reason why nickel cannot be forge welded is that it is attacked by the oxygen of the air blast and by the sulphur from the coal or fuel gas.

PART 8. LEAD

With the exception of copper there is more lead sold in the United States than any other non-ferrous metal, the approximate consumption per year now being nearly 500,000 tons. Three of the common forms of lead are white lead, red lead and blue lead.

It is the blue lead products which are of special interest to welders, as it is the kind of lead from which are manufactured sheet lead, lead pipe, cable covering, lead castings, caulking lead, etc.

Sheet Lead

After lead is extracted from the ore it is rolled in sheets of sizes up to 12 ft. long x 4½ ft. wide x 4½ in. thick, the weight of such a piece being equal to about 7 tons. The slabs are rolled backward and forth until longer thinner sheets are produced, down to 1/64 in. thick. Sheet lead is sold and known by its weight per square foot as, for example, 8 lb. lead is ⅛ of an inch thick and a square foot of that thickness would weigh 8 lb., 2 lb. lead being 1/32 of an inch thick and weighing 2 lb. per square foot. Up to ¼ in.

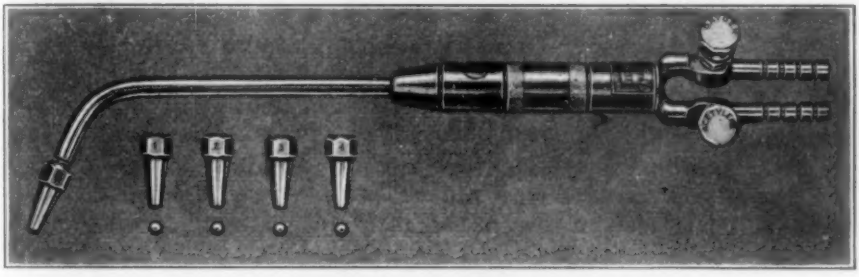

Fig. 8—Oxyacetylene Torch for Welding Lead

the thickness of lead advances in 64ths of an inch, the weight being 1 lb. for each 1/64 in. of thickness, so that 4 lb. lead would be 4/64 in. thick and 8 lb. lead would be 8/64 in. thick. This rule, however, holds only up to ¼ in. thick. It will be of interest to add that large sheets of lead are shipped by rolling them around wooden mandrels, often the trunk of a tree.

Welding Sheet Lead

The welding of sheet lead, mistakenly called *lead burning*, is being so successfully accomplished by the principle of fusion with the oxyacetylene torch that much of the former practice of soldering lead joints has been discontinued. Both the butt and lap forms of joints are used, the practice being to fuse the two pieces together without the use, in most cases, of a welding rod. For butt welds the metal is fused when in the dull molten condition, that is, when it flows sluggishly. At this temperature the grains of the metal hold together with sufficient force to prevent the air attacking the inner surfaces and forming oxides, which would cause a weld to be porous. In making a lap weld it is customary to remove all oxides and dirt from the surface with a sharp scraper, and the overlapping of the joint usually amounts to about ½ in. It is sometimes the practice to paint the surface of the lead with asphaltum directly adjoining the surface to be welded, which tends to

insulate the covered lead from the full effects of the flame. Welding rod is usually not necessary in a lap weld, the edge of the overlapping sheet simply being melted down and fused with the undersheet. In making a lead weld the heat should be confined as much as possible to the area to be welded so as not to affect the strength of the adjacent metal. This has led to the use of oxygen and acetylene which makes a quick acting positive flame as compared with the heat produced from the earlier use of other flames. A comparatively large size tip, and straightaway welding, is better than a smaller size tip and circling the torch to spread the heat.

Lead Pipe

In the earliest times lead pipe was made by bending a piece of sheet lead over a mandrel and melting the two abutting edges together. This method is still used on large size lead pipe, but lead pipe of ordinary dimensions is now manufactured by the process of extrusion, that is, by forcing the lead through a die by hydraulic pressure. Molten lead in a large cylinder is allowed to cool sufficiently to make it plastic, after which it is forced down through a die opening in a cylinder the size of the pipe desired. In the center of this die is a steel pin, or core, which causes the molten lead to take the form of a hollow pipe rather than a solid piece of metal. By this method the pipe is made without a seam. The pressure required to extrude lead runs from 10,000 lb. to 45,000 lb. per square inch, the higher pressure being necessary for the smaller size pipes. Lead pipe is made in sizes from 12 in. down to 1/16-in. inside diameter. They are sold by their weight. In another use of lead for pipe the lead serves as the lining for the inside of wrought iron pipe in which case the lead is poured into the iron pipe as it stands on end, around a steel core.

Welding Lead Pipe

Lead pipe may be butt welded end to end satisfactorily with the oxyacetylene torch, a strip of the metal being used as welding rod if necessary on the larger pipes.

Melting Lead Pipe Joints

Another interesting use of the oxyacetylene torch on lead is in melting the caulking from the bell-and-spigot joints of cast iron pipe. In this work it is the practice to start to melt the metal at the top and down each side until the lead has been removed over about two-thirds of the circumference. After this the joint can usually be pulled apart.

Smoking Molds

An interesting application of the oxyacetylene torch, burning only acetylene, is in the smoking of cast iron molds for making lead grids for storage batteries. The object is to coat the face

of the cast iron mold with carbon so that the molten metal poured into the mold will not stick to its face. The principle used in this work is the same as that practiced in all foundries where the sand molds have their surfaces coated with graphite by dusting or spreading it over the surfaces. The graphite burns and forms a gas wall between the sand and hot metal, thus preventing the sand from sticking to the casting. Likewise in the lead grid molds the carbon deposited by the acetylene torch is heated hot enough to instantly form a light film of gas which prevents the lead from actually touching the cast iron mold until after it is cooled and set. To put the carbon facing on the mold a regulator is placed on an acetylene cylinder and a small torch connected to it by rubber hose. Only a few pounds' pressure on the torch is required, just enough to make a flame about a foot long. No compressed oxygen is required, the partial combustion of the acetylene being produced by the oxygen of the air. The flame is passed back and forth over the face of the metal until it is heavily covered with unburnt carbon, after which the mold is ready for the lead to be poured. The smoking of molds for lead grids has become common practice in storage battery plants.

Chemical and Physical Properties

The best lead comes from an ore called *Galena*. After it is sent through a process of separation and roasting for the removal of some of its impurities, it is smelted usually in a tall blast furnace, the fuel being coke. After the smelting the lead is pure with the exception of small quantities of silver, copper, antimony, etc., which are removed by further refining. Refined lead is cast and sold in pigs from 15 to 18 in. long which weigh from 75 to 100 lb. The final condition of the lead as it is ready for the market would show an average chemical analysis about as follows:

	Per cent
Silver	.0004
Arsenic	Trace
Antimony	.0030
Tin	None
Bismuth	.0030
Copper	.0003
Cadmium	None
Iron	.0015
Zinc	Trace
Cobalt and Nickel	None
Manganese	None
Total Impurities	.0082
Pure Lead	99.9918
	100.00

Lead corrodes so slowly that sheet lead and lead pipe after many hundreds of years are still to be found in good condition. The melting point of lead is 621 deg. Fahr. Its weight is usually taken as 0.4106 lb. per cubic inch, its tensile strength about 2200 lb. per square inch, and its elastic limit as 950 lb. per square inch. It is hot short just below the melting point. It is made hard by alloying it with antimony or arsenic. It shrinks in castings at the rate of 0.3125 in. per foot.

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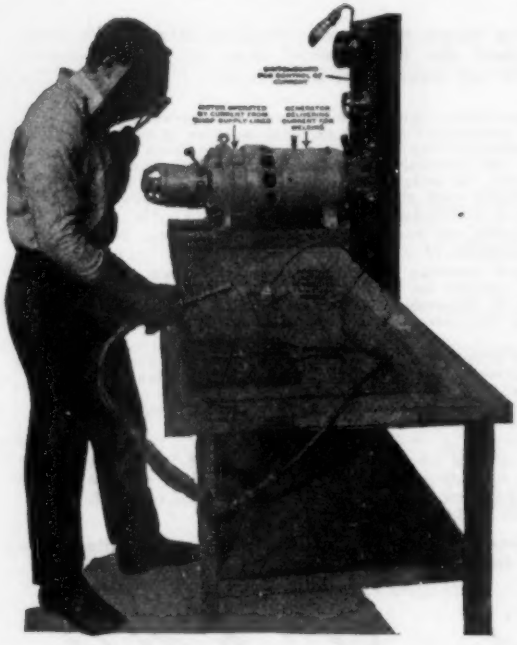

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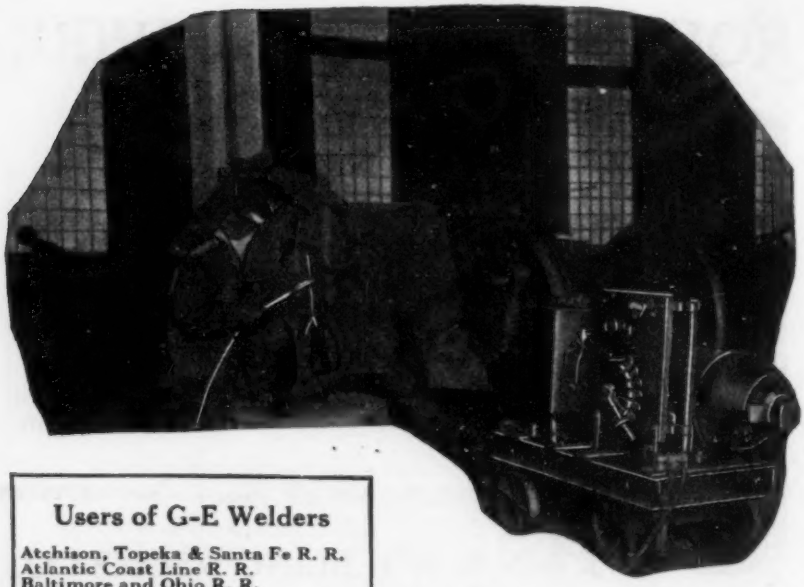

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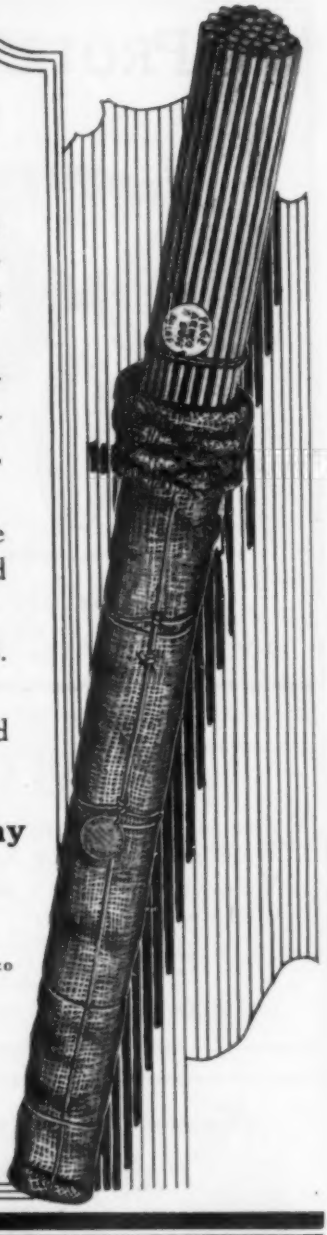

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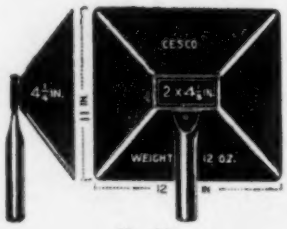

No. 10

CESCO HAND SHIELD

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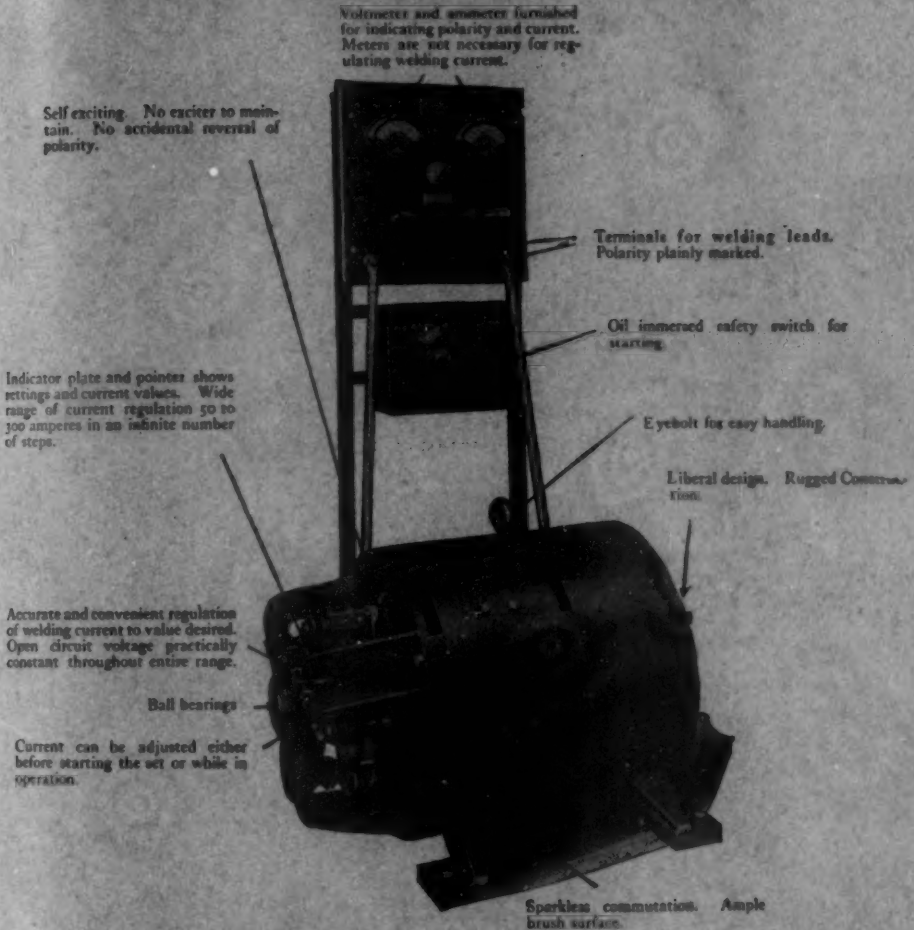
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